

**AD-786 616**

**CONCEPT FOR ATTENUATION OF THE BACK  
BLAST REGION OF A 105 mm RECOILLESS RIFLE**

**Hugo J. Nielsen**

**IIT Research Institute**

**Prepared for:**

**Watervliet Arsenal**

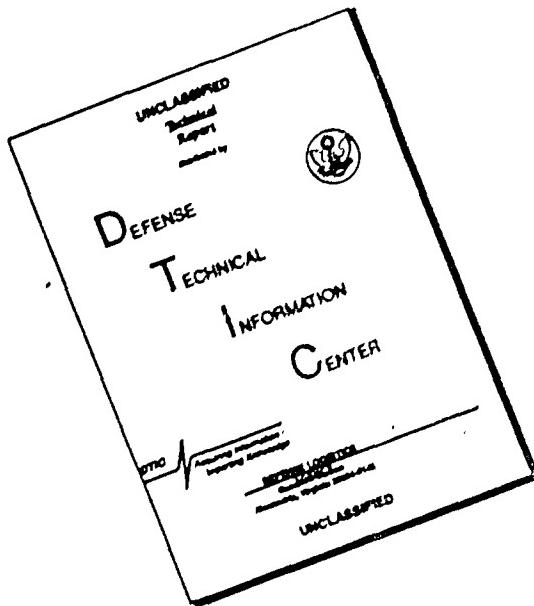
**July 1974**

**DISTRIBUTED BY:**



**National Technical Information Service  
U. S. DEPARTMENT OF COMMERCE  
5205 Port Royal Road, Springfield Va. 22151**

# **DISCLAIMER NOTICE**



**THIS DOCUMENT IS BEST  
QUALITY AVAILABLE. THE COPY  
FURNISHED TO DTIC CONTAINED  
A SIGNIFICANT NUMBER OF  
PAGES WHICH DO NOT  
REPRODUCE LEGIBLY.**

**UNCLASSIFIED**

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

<b>REPORT DOCUMENTATION PAGE</b>		<b>READ INSTRUCTIONS BEFORE COMPLETING FORM</b>															
1. REPORT NUMBER <b>WVT-CR-74026</b>	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER <b>AD-786616</b>															
4. TITLE (and Subtitle) Concept for Attenuation of the Back Blast Region of a 105 mm Recoilless Rifle		5. TYPE OF REPORT & PERIOD COVERED															
7. AUTHOR(s) Hugo J. Nielsen		6. PERFORMING ORG. REPORT NUMBER <b>J6293 (Sep 1973)</b>															
9. PERFORMING ORGANIZATION NAME AND ADDRESS IIT Research Institute 10 West 35th St. Chicago, Illinois 60616		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCAMS No. 513F.12.05014.02 DA Project No. 1F163206D050 Pron No. EJ-2-50139-(01)-M7-M7															
11. CONTROLLING OFFICE NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal Watervliet, N.Y. 12189		12. REPORT DATE <b>July 1974</b>															
14. NAME OF PUBLISHING AGENCY NAME & ADDRESS (If different from Controlling Office)		13. NUMBER OF PAGES															
		15. SECURITY CLASS. (of this report) <b>UNCLASSIFIED</b>															
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE															
16. DISTRIBUTION STATEMENT (of this Report)  Approved for release; distribution unlimited.																	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, If different from Report)																	
18. SUPPLEMENTARY NOTES																	
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%; padding-right: 10px;">Recoilless Rifles</td> <td style="width: 33%; padding-right: 10px;">Interior Ballistics</td> <td style="width: 33%; padding-right: 10px;">Report prepared by</td> </tr> <tr> <td>Air Blast</td> <td>Fluid Dynamics</td> <td>NATIONAL TECHNICAL</td> </tr> <tr> <td>Blast Attenuation</td> <td>Breech Blast</td> <td>INFORMATION SERVICE</td> </tr> <tr> <td>Two-Phase Flow</td> <td>Davis Gun</td> <td>U.S. Department of Commerce</td> </tr> <tr> <td></td> <td></td> <td>Springfield, V.A. 22131</td> </tr> </table>			Recoilless Rifles	Interior Ballistics	Report prepared by	Air Blast	Fluid Dynamics	NATIONAL TECHNICAL	Blast Attenuation	Breech Blast	INFORMATION SERVICE	Two-Phase Flow	Davis Gun	U.S. Department of Commerce			Springfield, V.A. 22131
Recoilless Rifles	Interior Ballistics	Report prepared by															
Air Blast	Fluid Dynamics	NATIONAL TECHNICAL															
Blast Attenuation	Breech Blast	INFORMATION SERVICE															
Two-Phase Flow	Davis Gun	U.S. Department of Commerce															
		Springfield, V.A. 22131															
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  <p>A concept for attenuating the back blast field of a recoilless rifle by the ejection of liquid or solid particles was investigated with respect to feasibility. The concept involves attaching a cylinder partially filled with liquid or solid particles to the nozzle. In this way the propellant gas is forced to expend some of its energy in driving the particles out of the cylinder and the duration of the flow of propellant gas into the blast field is altered.</p> <p style="text-align: center;">SEE REVERSE SIDE</p>																	

INCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ABSTRACT (Continued)

Block No. 20

The feasibility of the concept was investigated computationally. Computer programs were prepared to solve the gas dynamics of the blast field which included traveling particles. Computational procedures were used that are analogous to current single phase gas dynamics methods, but which are also based on the conservation relations for mass, momentum and energy in multiphase systems. The velocity and temperature of the gas and particles are allowed to be different in this computational procedure.

The results of the investigation, are that attenuation of the blast field is possible if the attached cylinder is long and the total weight of the expelled particles approaches the weight of the projectile. For shorter cylinders and smaller weights of particles, the blast field is not attenuated. Thus, the blast attenuation concept studied is feasible only in a rifle which is encumbered with an attachment which is so heavy the rifle is no longer a practical weapon.

1a

INCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

**A**

DISPOSITION

Destroy this report when it is no longer needed. Do not return it to the originator.

DISCLAIMER

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

*if*

WVT-CR-74026

AD

CONCEPT FOR ATTENUATION OF THE BACK BLAST  
REGION OF A 105 MM RECOILLESS RIFLE

PREPARED BY

HUGO J. NIELSEN  
IIT Research Institute  
10 West 35th Street  
Chicago, Illinois 60616

PREPARED FOR



BENET WEAPONS LABORATORY  
WATERVLIET ARSENAL  
WATERVLIET, N.Y. 12189

JULY 1974

**TECHNICAL REPORT**

AMCMS No. 513F.12.0:014.02

DA Project No. 1F163206D050

Pron No. EJ-2-50139-(01)-M7-M7

Contract No. DAAF07-73-C-0155

APPROVED FOR PUBLIC RELEASE. DISTRIBUTION UNLIMITED

;C

## FOREWORD

This is the final report on Contract DAAF07-73-C-0155 for Watervliet Arsenal, IIT Research Institute Project J6293. Charles C. Andrade was project monitor. A significant contribution to the effort described in this report was made by Arnold Wiedermann in the area of mechanisms that would influence the blast field and assistance in the programming effort.

Respectfully submitted,  
IIT Research Institute



Hugo J. Nielsen  
Senior Research Engineer  
Safety Research

Approved by



K. E. McKee  
Director of Research  
Engineering Mechanics Division

## TABLE OF CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. BLAST ATTENUATION	2
a. Basic Mechanism	2
b. Approaches for Implementing the Blast Attenuating Mechanism	4
(1) Davis Gas	5
(2) Short Cylinder Concept	6
3. MATHEMATICAL MODELING	6
a. Conservation Relations	
(1) Mass Conservation	7
(2) Momentum Conservation	9
(3) Energy Conservation	11
b. Subsidiary Relations	12
c. Computational Procedure	15
4. RESULTS	20
5. SUMMARY OF RESULTS AND CONCLUSIONS	34
REFERENCES	35
APPENDIX A - ONE-DIMENSIONAL GAS PARTICLE FLOW	A-1
APPENDIX B - TWO-DIMENSIONAL GAS PARTICLE FLOW	B-1

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1a	Distance of Wave Propagation	3
1b	Pressure Profile at Various Distances from Nozzle	3
2	Elemental Cell	8
3	Element Spatial Distribution with Interleaving of Velocity Points Between Points at Which Density, Energy, Pressure and Composition are Calculated	18
4	Recoilless Rifle and Distribution of Nodes in Finite Difference Grid	19
5	Chamber Pressure; No Water	21
6	Chamber Pressure; 5 lb Water, 5 mm Drop Size	22
7	Chamber Pressure; 5 lb Water, 1 mm Drop Size	23
8	Projectile Velocity and Travel Distance, No Water	24
9	Projectile Velocity and Travel Distance, 5 lb Water, 5 mm Drop Size	25
10	Projectile Velocity and Travel Distance, 5 lb Water, 1 mm Drop Size	26
11	Pressure Profile Contours, 3.5 Msec After Ignition, 5 lb Water, 1 mm Drop Size	28
12	Pressure Profile Contours, 5.7 Msec After Ignition, 5 lb water, 1 mm Drop Size	29
13	Location of Points in Blast Field for which Pressure is Plotted as a Function of Time	30
14	Pressure (Static Plus Dynamic) vs Time with No Water in the Cylinder	31
15	Pressure (Static Plus Dynamic) vs Time with 5 lb of Water in the Cylinder Assumed Drop Size, 5 mm	32
16	Pressure (Static Plus Dynamic) vs Time with 5 lb of Water in the Cylinder, Drop Size, 1 mm	33

## 1. INTRODUCTION

The army is currently investigating methods for arming helicopters with weapons of greater firepower. A major difficulty stems from the relatively weak helicopter structure which cannot sustain the recoil of most large caliber weapons. Although recoilless rifles obviate one problem, the blast field created by propellant gases discharged through the rifle nozzle creates other problems. Damaging peak overpressures of several pounds per square inch would be produced on some parts of the helicopter fuselage.

Constraints which arise from considerations of loading, firing, etc., prevent mounting the rifle so that the blast field does not affect the helicopter's structure. Moreover, severe weight penalties are involved in shielding the fuselage or employing ducts to carry away the nozzle blast gases. The net effect of these constraints is to make the feasibility of arming helicopters with recoilless rifles depend on finding a means for attenuating the intensity of the blast field.

A particular concept for attenuating the blast field was investigated. The concept involves attaching a short cylinder filled with water or solid particles to the rifle nozzle to delay the emergence of propellant gas. The flowing propellant gas would be slowed by driving the particles\* out of the cylinder, thereby reducing the blast pressure, if the expelled liquid or solid does not give up its acquired momentum to the atmosphere too rapidly after it emerges from the cylinder.

The approach taken in this investigation is to develop a computational method and program for describing the blast field produced by the particles expelled from the cylinder. This is accomplished by extending the numerical methods presently used for solving unsteady compressible single component flows to a multiphase flow where the velocity and temperature of the particles can be different from that of the gas in which they are suspended.

\*The word "particles" as used herein refers to solid or liquid particles.

## 2. BLAST ATTENUATION

### a. Basic Mechanism

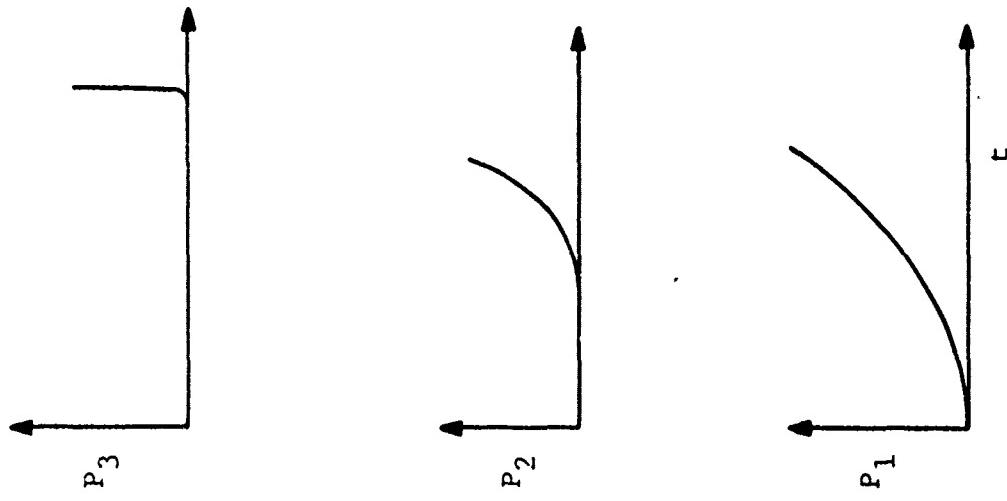
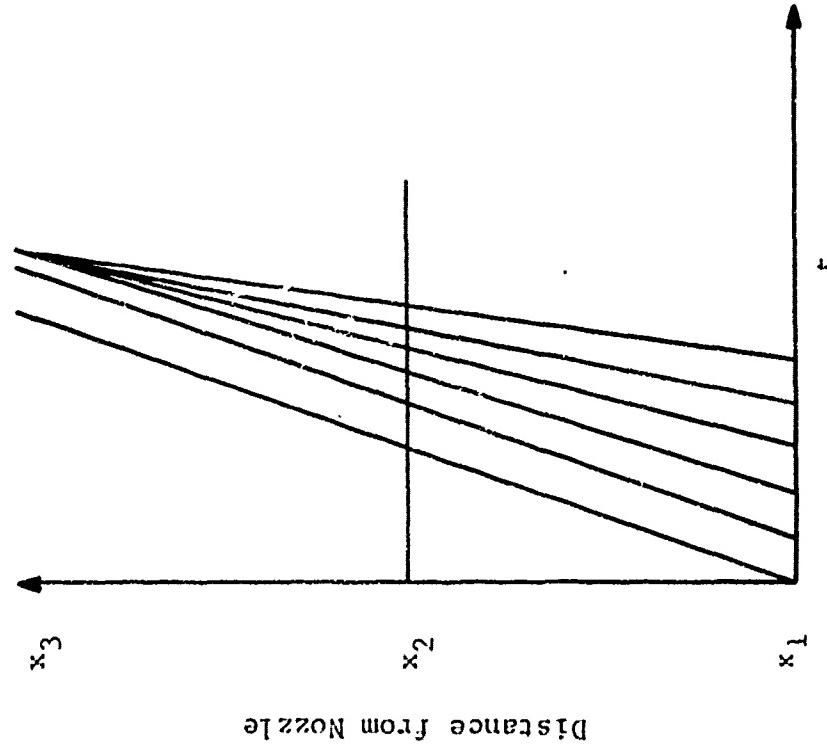
The blast field behind a recoilless rifle depends mainly upon two factors, the total energy of the propellant gas flowing through the nozzle and the duration of the flow. Since the comparative importance of these factors varies with the distance from the nozzle, it is desirable to have an assessment of the distances in which one or the other has a predominant influence.

The distribution of pressure, density, energy or velocity in the blast field can be regarded as a system of traveling waves in which the local wave speed is the speed of sound. As the propellant gas flows into the blast field and raises the temperature by the effect of compression or by the convection of gases of higher temperature, the wave speed increases. A consequence of this is that a profile of pressure versus time that formerly rose gradually to the peak pressure in the vicinity of the nozzle, changes so that it rises more rapidly at greater distances. As one considers increasing distances from the nozzle the pressure profile eventually steepens to form a shock wave. The process takes place as illustrated in Figs. 1a and 1b. For distances large enough for the profile to steepen up to a shock wave the pressure is independent of the duration of the nozzle flow and only depends on the total energy of the gas and the distance from the nozzle. If the shock pressure were still strong compared to the ambient pressure at these distances it would approach the Taylor's result for a point source explosion (Ref. 1),

$$p \propto E_t / R^3 \quad (1)$$

---

1. Taylor, G., "The Formation of a Blast Wave by a Very Intense Explosion," Vol. 201.



where

$E_t$  = total energy released by explosion  
or in propellant gases

p = pressure

R = realistic distance from source

Although Taylor's result may not be useful for a quantitative estimate of the blast pressure in the problem of concern, the indicated linear dependence of the pressure on the total gas energy is probably a good guide.

These preliminary considerations of the propagation of the blast wave show that for positions in the blast field beyond the distance where a shock wave forms, the only means for attenuating blast intensity is to reduce the total energy in the propellant gas. At lesser distances, nozzle flow duration is a factor and prolonging it would result in reduced peak pressure. An approximation of the distance required for the formation of the shock wave can be made as follows. The temperature of the propellant gas increases the speed of sound two to three times over that which exists in ambient air. The peak chamber pressure is reached about 6 msec after ignition. Equating the travel distances for waves emitted at the initial and peak pressure conditions and assuming that the waves at the peak condition travel at a speed three times greater than the others, yields a distance of 10 ft.

The area of interest on the helicopter extends from about 3 to 10 ft from the fuselage. For much of this area it is apparent that both of the factors discussed will influence the blast pressure, but at the extremity the peak pressure is determined by the total energy in the propellant gases.

b. Approaches for Implementing the Blast Attenuating Mechanism

Two recoilless rifle configurations were considered in which particles are expelled. Each epitomizes a different blast attenuation mechanism: (1) reduction of total energy, and (2) prolongation of flow duration.

(1) Davis Gas

A rifle based on this principle would consist of a straight tube in which particles are expelled from one end and the projectile from the other. Since the momentum of the particles must equal that of the projectile to fulfill the requirements for cancellation of recoil, the tube length required is large unless the weight of the particles is much larger than that of the projectile. For particles of weight equal to the projectile, the tube length would be twice that of a conventional rifle and, therefore, impractical. The blast pressure is reduced because the gas does not escape from the rifle freely until the particles are expelled from the tube. An estimate of the energy removed from the propellant gas by accelerating the projectile and particles may be obtained by assuming that the expansion is isentropic,

$$\frac{e_2}{e_1} = (\text{volume ratio})^{\nu-1} = 0.66 \quad (2)$$

where

$e_1$  = initial internal energy

$e_2$  = internal energy when propellant gas emerges

$\nu$  = ratio of specific heat, 1.21 for propellant  
gas volume ratio = 1/7, chamber-to-chamber  
plus barrel volume

About one-third of the energy in the propellant gas is removed and the approximate effect on the blast field is proportional to the value given for the ratio of the emergent to the initial internal energy.

This concept provides a means for reducing the blast intensity and shows that it is feasible to attenuate the blast pressure by expelling particles. The question remaining is, do the expelled particles release their acquired momentum to the air after exiting? If the particles remain as a coherent mass, they would not; if they expand rapidly, the drag forces acting on the particles would cause

them to transmit their momentum to the air again and produce a blast field. This problem is dealt with by means of the two-dimensional blast field code discussed in the following section. A listing of one- and two-dimensional codes is provided in Appendices A and B.

#### (2) Short Cylinder Concept

This concept was developed in an attempt to achieve blast attenuation without the excessive length of the Davis gun. The cylinder from which particles are expelled is shorter and a nozzle is used between the cylinder and rifle chamber to permit the chamber pressure to build up properly. With the shorter cylinder, the amount of energy that can be removed from the propellant gas is less than with the Davis Gas concept. To have a significant reduction in the intensity of the blast field, the effect of flow duration has to be exploited. In this study, the particles are not compacted and the propellant gas is permitted to leak through void spaces, thus prolonging the flow period. Since the particles are not attached to the cylinder and do not transmit an axial load to it, the recoilless properties of the rifle are not affected significantly by the cylinder.

#### 3. MATHEMATICAL MODELING

The physical problem to be modeled involves the motion of liquid droplets or solid particles through a gas in which strong compressible effects take place that include the formation of shock waves. Because the temperature and velocity of the particles are not usually the same as of the gas at the same location, various interactions take place between the gas and the suspended

particles. The effects of drag and heat transfer cause momentum and energy to be transferred between the gas and the particles. The motion and temperature of the gas therefore, are different than in an analogous flow case without particles.

A numerical method is developed for the solution of this problem that is patterned after the same techniques used for the numerical solution of single component flows. Conservation relations for the mass, momentum and energy are developed for the gas and particle phases and these relations are then expressed in finite difference form for solution by numerical methods. Approaches to the development of the conservation relations and some solution for particular flow cases are summarized by Soo (Ref. 2) and Marble (Ref. 3).

#### a. Conservation Relations

The conservation relations are developed for an elemental cell as indicated in Fig. 2. Particle sizes and mean separation distances are assumed to be small relative to the size of the cell. This limits the applicability of the method to problems in which the mean particle separation distance is small relative to the system size and the scale of the phenomena of interest.

##### (1) Mass Conservation

Equating the accumulation of gas or particles to the net flux of gas or particles into the cell and the contributions due to evaporation and other effects, gives the following expressions for the gaseous and particle phases:

- 
2. Soo, S. L., Fluid Dynamics of Multiphase System, Blaudell Publishing Co., (1967).
  3. Marble, F. E., "Dynamics of Dusty Gases," Annual Rev. Fluid Mech., Vol. 2, (1970).

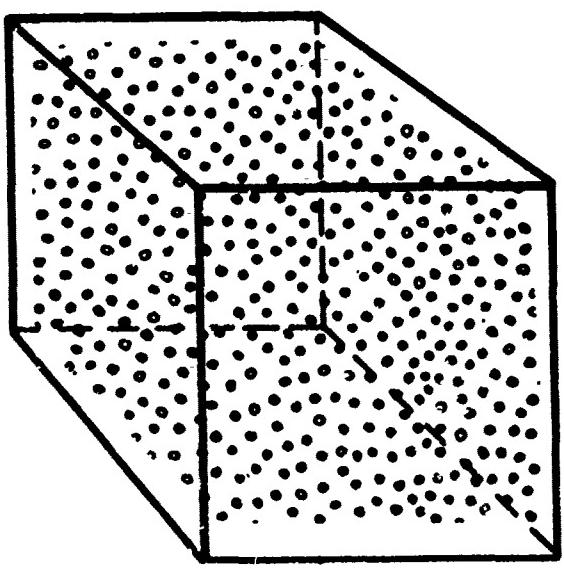


Figure 2 ELEMENTAL CELL.

$$\frac{\partial c_g}{\partial t} = - \nabla \cdot \vec{u}_g c_g + N w_e + w_{pb} \quad (3)$$

$$\frac{\partial c_d}{\partial t} = - \nabla \cdot \vec{u}_d c_d - N w_e \quad (4)$$

$$\frac{\partial N}{\partial t} = - \nabla \cdot \vec{u}_d N \quad (5)$$

where

$c_g$  = concentration of gas

$c_d$  = concentration of matter present as particles

$N$  = number of particles per unit volume

$t$  = time

$\vec{u}_d$  = velocity of particles

$\vec{u}_g$  = velocity of gas

$w_e$  = mass loss of a single particle by vaporization

$w_{pb}$  = mass addition by propellant burning

## (2) Momentum Conservation

When one considers the motion of a single particle the governing equation is obtained by equating the Lagrangian acceleration to the drag force and the pressure difference across the particle.

$$m \frac{D\vec{u}_d}{Dt} = - \vec{D} - V \nabla p \quad (6)$$

where

$\vec{D}$  = drag force vector

$m$  = mass of the particle

$p$  = pressure

$V$  = volume of the particle

For the purpose of the computational method to be developed, a Eulerian expression (i.e., at a fixed point for the derivative), is required and can be obtained if the number of particles within the cell indicated in Fig. 2 is large enough so that the mean velocity is reasonably well defined and can be assumed to be continuous.

$$m \frac{\partial \vec{u}_d}{\partial t} = - m \vec{u}_d \cdot \nabla \vec{u}_d - \vec{D} - V V_p \quad (7)$$

Multiplying through by the number of particles and using Eq. (4) gives the following for the momentum of the particle phase.

$$\frac{\partial c_d \vec{u}_d}{\partial t} = - \nabla \cdot c_d \vec{u}_d; \vec{u}_d - ND - \frac{c_d}{\rho_d} \nabla p \quad (8)$$

where  $\rho_d$  is the density of the material of which the particles are composed.

Although the dyadic notation used ( $V \cdot cu$ ;  $u$ ) is inconvenient, it permits the development of a conservative computational scheme, i.e., one in which the accumulation of momentum in the computational grid is exactly consistent with the fluxes of momentum over the grid boundaries. The alternative and more common expression for acceleration ( $\vec{u} \cdot \nabla \vec{u}$ ), does not permit this.

The momentum equation for the gas phase may be obtained by subtracting the equation for the particle momentum derived here from the equations for total momentum of both the gas and the particles. However, the experience obtained with various different computation procedures with this problem, showed that a more stable program is obtained if the computational procedure is based on the equations for the total momentum of both the gas and particles and the momentum of the particles alone rather than on the equations for the momentum of the gas and particle phases.

Equating the accumulation of the momentum to the fluxes across the cell boundaries and the effects of pressure, gives the following expression for the total momentum of both phases,

$$\frac{\partial}{\partial t} (c_g \vec{u}_g + c_d \vec{u}_d) = - \nabla \cdot (c_g \vec{u}_g; \vec{u}_g + c_d \vec{u}_d; \vec{u}_d) - \nabla p \quad (9)$$

Terms relating to particle drag do not appear in this equation since they control only the transfer of momentum between the gas and particle phases and thus do not add to or subtract from the momentum sum.

### (3) Energy Conservation

Considering again a single particle, the following equation is obtained for the temperature by equating the rate of change of stored sensible heat to the losses by convection and evaporative cooling.

$$m c_{pd} \frac{dT_d}{dt} = - (Q_c + Q_e) \quad (10)$$

where

$c_{pd}$  = specific heat of the particle

$Q_c$  = cooling rate of particle by convection

$Q_e$  = cooling rate of particle by evaporation

An Eulerian representation for the rate of temperature change can be obtained when the number of particles within the cell is large enough to permit a reasonable definition of a mean particle temperature.

$$c_{pd} \frac{\partial c_d T_d}{\partial t} + \nabla \cdot c_d \vec{u}_d T_d = - N(Q_c + Q_e) \quad (11)$$

An expression for the total energy in both phases is obtained by equating the rate of accumulation of energy to the fluxes and the work done by pressure effects at the cell boundaries.

$$\begin{aligned}
 & \frac{\partial}{\partial t} c_g (e_g + \frac{1}{2} \vec{u}_g \cdot \vec{u}_g) + c_d (c_{pd} T_d + \frac{1}{2} \vec{u}_d \cdot \vec{u}_d) \\
 & = - \nabla \cdot \vec{u}_g c_g (e_g + \frac{1}{2} \vec{u}_g \cdot \vec{u}_g) + VFP \\
 & - \nabla \cdot \vec{u}_d c_d (cT_d + \frac{1}{2} \vec{u}_d \cdot \vec{u}_d) + (1 - VF)p
 \end{aligned} \tag{12}$$

where

$e_g$  = internal energy of the gas phase

VF = void fraction

As in the case of the momentum equation, the computation scheme is more stable if the computations are based on the total energy and the energy in the particle stream. The gas phase energy is then obtained by calculating the difference in these quantities rather than by calculating the gas energy from an equation for the energy of the gas phase.

### b. Subsidiary Relations

To obtain solutions for the above set of equations, it is necessary to connect the concentration, pressure and density with an equation of state, to evaluate the drag forces and particle heat transfer rates that transfer momentum and energy between the gas and particle phases. A propellant burning law is also required to predict the rate at which mass and energy is added to the propellant gases.

#### Equation of State

Tabulated values for the thermodynamic properties of the propellant gas from 23 different military propellants are given in Ref. 4. For computational purposes a polynomial representation was used to fit the equation of state data. The following nine term polynomial was fitted by least squares to the data for M8 propellant with a maximum discrepancy of only 0.3 of 1 percent:

---

4. Baer, P. G. and Bryson, K. R., Tables of Computed Thermodynamics Properties of Military Gun Propellants, BNL Memo. Rept. No. 1338 (Mar. 1961).

$$p_R = \sum_{i=1}^3 \sum_{j=0}^2 A_{ij} \rho_g^i e_g^j \quad (13)$$

where

$\rho_g$  = density

$e_g$  = internal energy, including energy of formation as defined for  $e$  in Ref. 4

Numerical values for the coefficients  $A_{ij}$  are given in Appendix A in the subroutine entitled EQSTAT of the one-dimensional code.

The gas density to be used in this equation of state is determined from the amount of gas existing in a unit volume and the void fraction.

$$VF = 1 - \frac{c_d}{pd} \quad (14)$$

$$\rho_g = c_g / V \quad (15)$$

### • Drag Forces

Drag forces acting on the drops are calculated from the drag coefficient and the dynamic pressure as follows:

$$D = C_d \frac{\pi}{4} a^2 \rho_g \left| \vec{u}_d - \vec{u}_g \right| \frac{(\vec{u}_d - \vec{u}_g)}{2} \quad (16)$$

where

$a$  = particle diameter

$C_d$  = drag coefficient

$\rho_g$  = gas density

Absolute values of the velocity difference are used in the manner shown to preserve the proper sign and direction of the drag force irrespective of the sign of the velocity difference.

---

4. Baer, P. G. and Bryson, K. R., Tables of Computed Thermodynamics Properties of Military Gun Propellants, BRL Memo. Rept. No. 1338 (Mar. 1961).

Coefficients of drag  $C_d$  are obtained from the particle Reynolds number  $Re$  as shown, Ref. 5

$$C_d = \frac{24}{Re} \quad Re < 2.05 \quad (17)$$

$$C_d = \frac{18}{Re} 0.6 \quad 2.05 < Re < 486 \quad (18)$$

$$C_d = 0.44 \quad 486 < Re \quad (19)$$

where

$$Re = \frac{\rho_g a |u_d - u_g|}{\mu_g}$$

$\mu_g$  = gas viscosity

#### • Heat Exchange

The rate at which heat is transferred from the gas to the particulate phase is obtained from correlations for the heat transfer coefficient on a single particle (Ref. 6),

$$\frac{ha}{k_g} = 2 + 0.34 Re^{0.6} Pr^{1/3} \quad (20)$$

where

$h$  = heat transfer coefficient

$k_g$  = thermal conductivity of the gas

$Pr$  = Prandtl number of the gas

The heat transfer rate,  $Q$ , is given by

$$Q = \pi a^2 h(T_g - T_d) \quad (21)$$

5. Perry, J. H., Chemical Engineering Handbook, McGraw-Hill Publishing Co. (1950).

6. McAdams, Heat Transmission, McGraw-Hill Publishing Co. (1954).

where

$T_g$  = the gas temperature.

• Propellant Burning Law

The rate at which gas and energy is added to the propellant gas will be computed from surface regression rate of the burning propellant. Watervliet Arsenal provided the following correlation for the propellant to be considered.

$$R = 0.00186 p^{0.83} \quad (22)$$

where  $p$  is the pressure in pounds per square inch and  $R$  is the regression rate of the propellant surface in inches per second.

c. Computational Procedure

For the purpose of presenting the numerical method by which solutions to the preceding equation may be obtained, it is useful to use a more compact notation. Each of the differential Eqs. (3), (4), (5), (8), (9), (11) and (12) can be expressed in the following form.

$$\frac{\partial r_n}{\partial t} + \frac{\partial r(u_n + v_n)}{\partial r} + r \frac{\partial v_n}{\partial r} + \frac{\partial r(w_n + \epsilon_n)}{\partial z} = r \xi_n \quad (23)$$

where  $r$  is the radial distance from the axis and  $z$  is the distance along the axis. Each of the variables  $\alpha$  to  $\xi$  are defined in Table I. The velocity components,  $u$  and  $w$ , are of the phase considered.

The numerical procedure is based on a finite difference form for each of the equations represented by Eq. 23. Conceptually, the field of interest is divided into discrete cells and the finite difference equations describe the rate of accumulation of mass, number of particles, momentum, energy, etc. in terms of the fluxes of these quantities across the cell boundaries and the other quantities appearing in Eq. 23. In the particular grid system used in this study, velocity is defined at the cell boundaries

Table I DEFINITION OF TERMS IN EQUATION

Conservation of	$\alpha$	$\beta$	$\gamma$	$\nu$	$\delta$	$\xi$
Gas	$c_g$	0	0	0	0	$NW_e + W_p g$
Particle Mass	$c_d$	0	0	0	0	$-NW_e$
Number of Particles	$N$	0	0	0	0	0
Radial Momentum of Particles	$c_d u_d$	0	0	0	0	$-ND_r - \frac{c_d}{\rho_d} \frac{\partial p}{\partial r}$
Radial Momentum of Gas and Particles	$c_g u_g + c_d u_d$	0	0	0	0	0
Axial Momentum of Particles	$c_d w_d$	0	0	0	0	$-ND_z - \frac{c_d}{\rho_d} \frac{\partial p}{\partial z}$
Axial Momentum of Gas and Particles	$c_g w_g + c_d w_d$	0	0	0	0	0
Energy of Particles	$c_{pd} c_d T_d$	0	0	0	0	$-N(Q_c + Q_e)$
Energy of Gas and Particles	$c_g (e_g + \frac{1}{2} u_g \cdot u_g)$ $+ c_d (c_{pd} T_d + \frac{1}{2} u_d \cdot u_d)$	$VF \cdot p \cdot u_g$ $+(1-VF) \cdot p \cdot u_d$	0	$VF \cdot p \cdot w_g$ $+(1-VF) \cdot p \cdot w_d$	0	0

and particle number, concentration, pressure energy and temperature are defined at the cell centers as indicated in Fig. 3. The fluxes across the cell boundaries are computed in accordance with the donor cell concept described by Gentry and Martin (Ref. 7). That is, the flux of particles for example, is calculated from the particle density in the cell which donates the particles.

Because velocity, in the computational procedure used here, is defined at the cell boundaries, computations for the momentum of the gas and of the particles are based on special cells displaced one half the distance between the grid lines so that it is centered over the points where the velocity is defined. The momentum,  $p_u$ , is thus based on the velocity at the special cell centers and an interpolated value for the density at that point. Similarly, the kinetic energy at the center of the cells where internal energy is defined is based on interpolated values for the kinetic energy.

Our experience with this computational procedure is that spurious negative values for the internal energy and pressure are obtained less frequently than with the more usual procedure in which the velocity is calculated for the same positions as the density and energy.

For the study of the blast field behind the weapon, the method would be implemented in a two-dimensional grid as shown in Fig. 4. The grid spacing increases with distance from the nozzle to accommodate a large region without an excessive number of grid points. Two computer programs were prepared for solving the blast field problem: (1) a one-dimensional program which describes the interior ballistics of the rifle and the flow from the cylinder; (2) a two-dimensional program which uses the flow from the cylinder as input and calculates the blast field.

- 
7. Gentry, R. A.; Martin, R. E.; and Daly, B. J., "An Eulerian Differencing Method for Unsteady Compressible Flow Problems," Computational Phys., Vol. 1, pp 87-118 (1966).

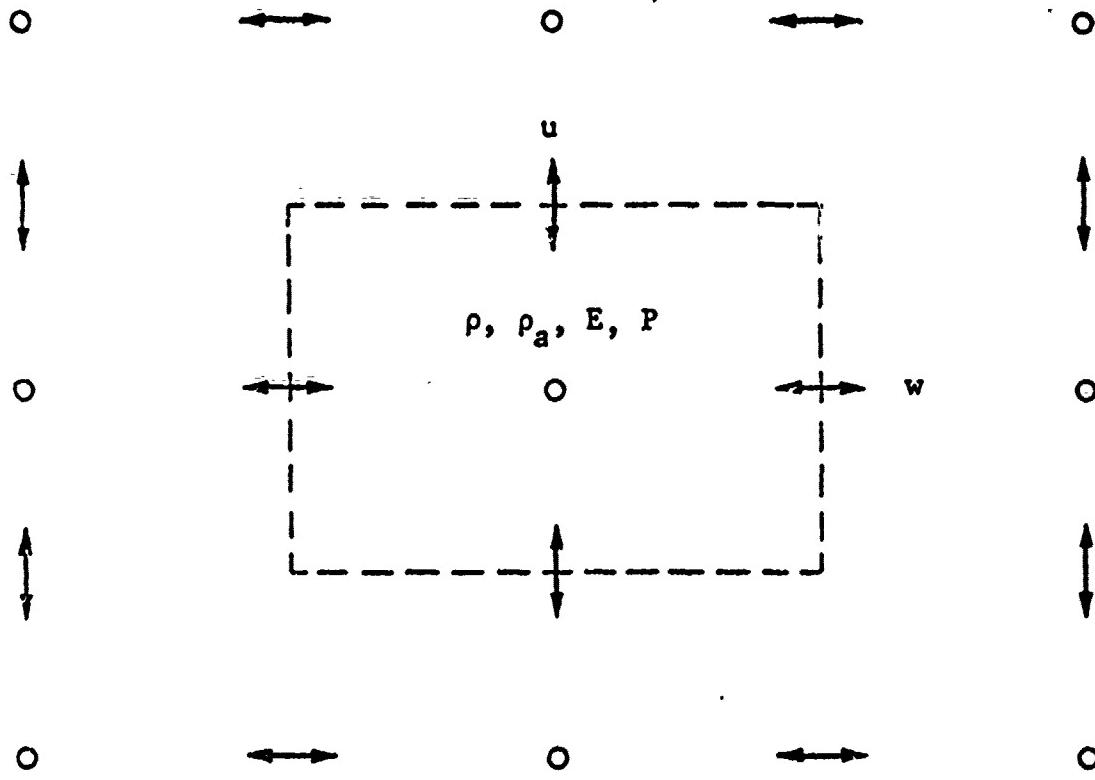


Figure 3

ELEMENT SPATIAL DISTRIBUTION WITH INTERLEAVING  
OF VELOCITY POINTS BETWEEN POINTS AT WHICH  
DENSITY, ENERGY, PRESSURE AND COMPOSITION ARE  
CALCULATED

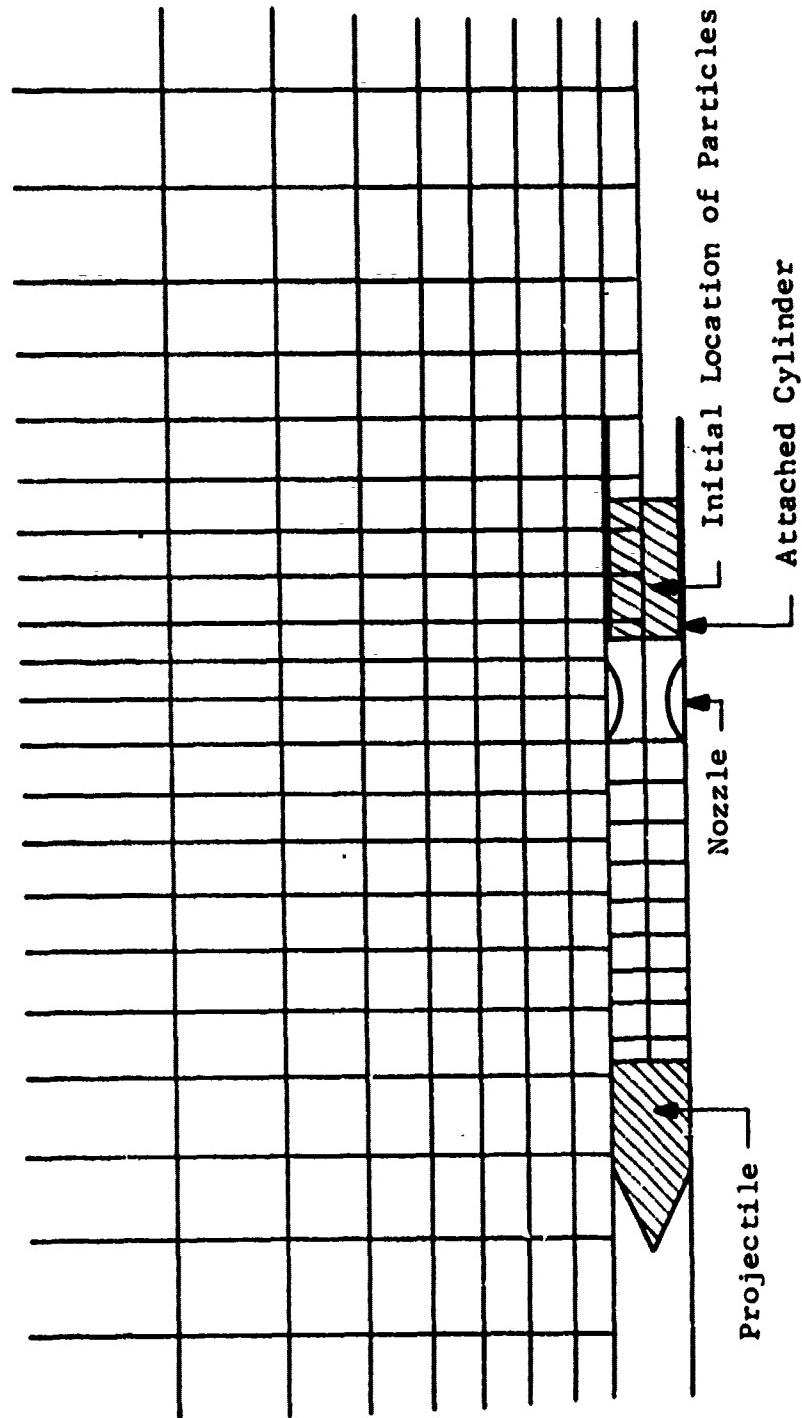


Figure 4 RECOILLESS RIFLE AND DISTRIBUTION OF NODES IN FINITE DIFFERENCE GRID

#### 4. RESULTS

The interior ballistics and nozzle blast field were calculated for the conditions defined by the following values:

charge	8.1 lb
web	0.061 in.
bore	105 mm
barrel length	140 in.
chamber volume	200 in.
cylinder diameter	7.4 in.
cylinder length	24 in.
throat diameter (effective)	3.26 in.

Results for three different conditions in the attached cylinder are presented:

- no water in the cylinder
- 5 lb of water with a drop size of 5 mm
- 5 lb of water with a drop size of 1 mm

Results obtained with the one-dimensional model which furnished the inputs for the two-dimensional model are given in the following figures. Chamber pressures are given in Figs. 5-7.

These were obtained by calculating the average value of the pressures at nodes in the chamber region of the gun. A value of approximately 8000 lb was obtained for the peak chamber pressure in each case. The peak pressure is shown to increase slightly when water is used in the cylinder and when the drop size is diminished. This is due to the resistance to the flow or propellant gas developed by the water drops which diminish the leak rate of the rifle. The abrupt drop in chamber pressure that occurs at about 15 msec, coincides with the burnout of propellant. Values obtained for the projectile travel and velocity while in the barrel are shown in Figs. 8-10.

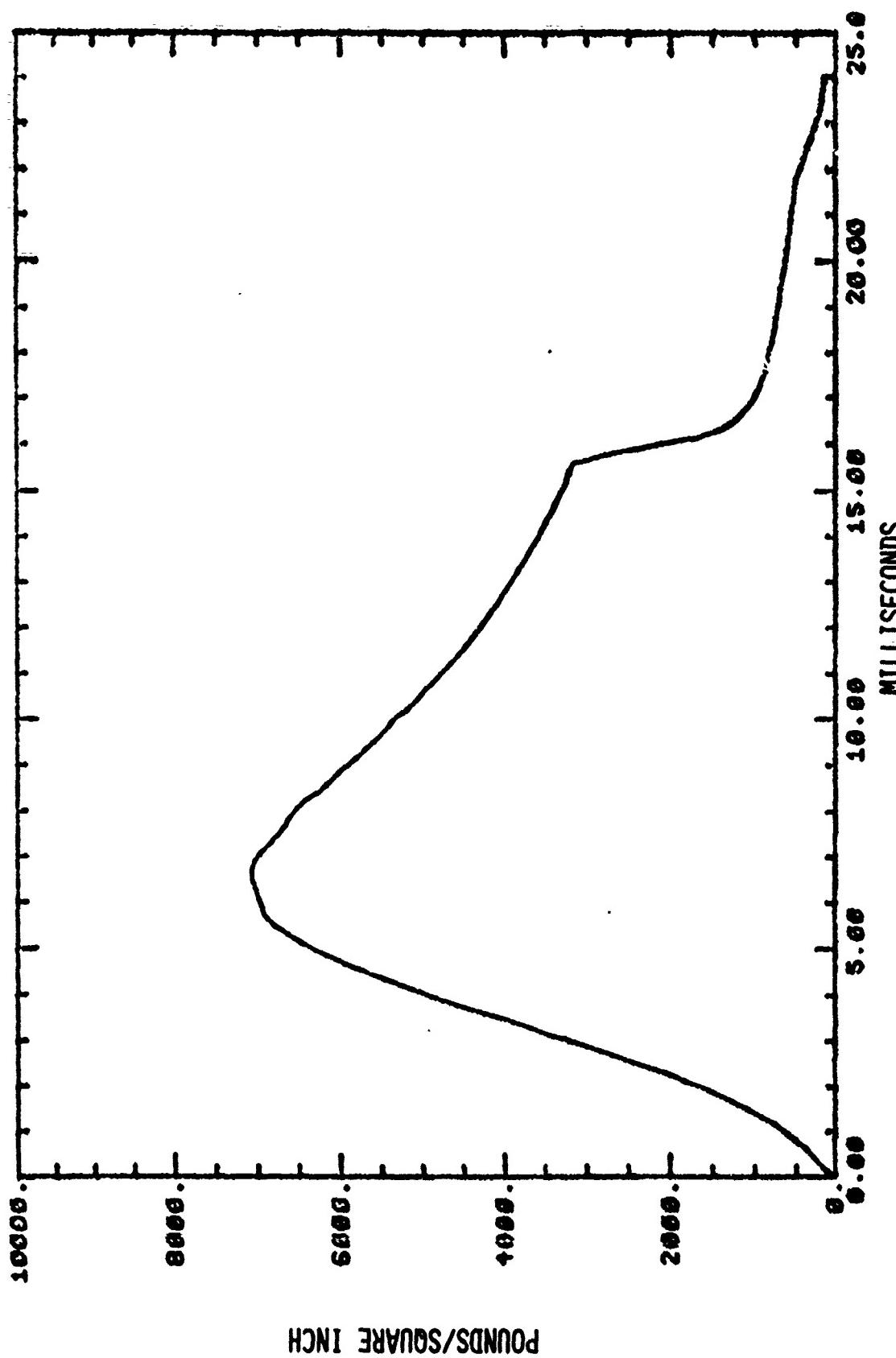


Figure 5 CHAMBER PRESSURE; NO WATER

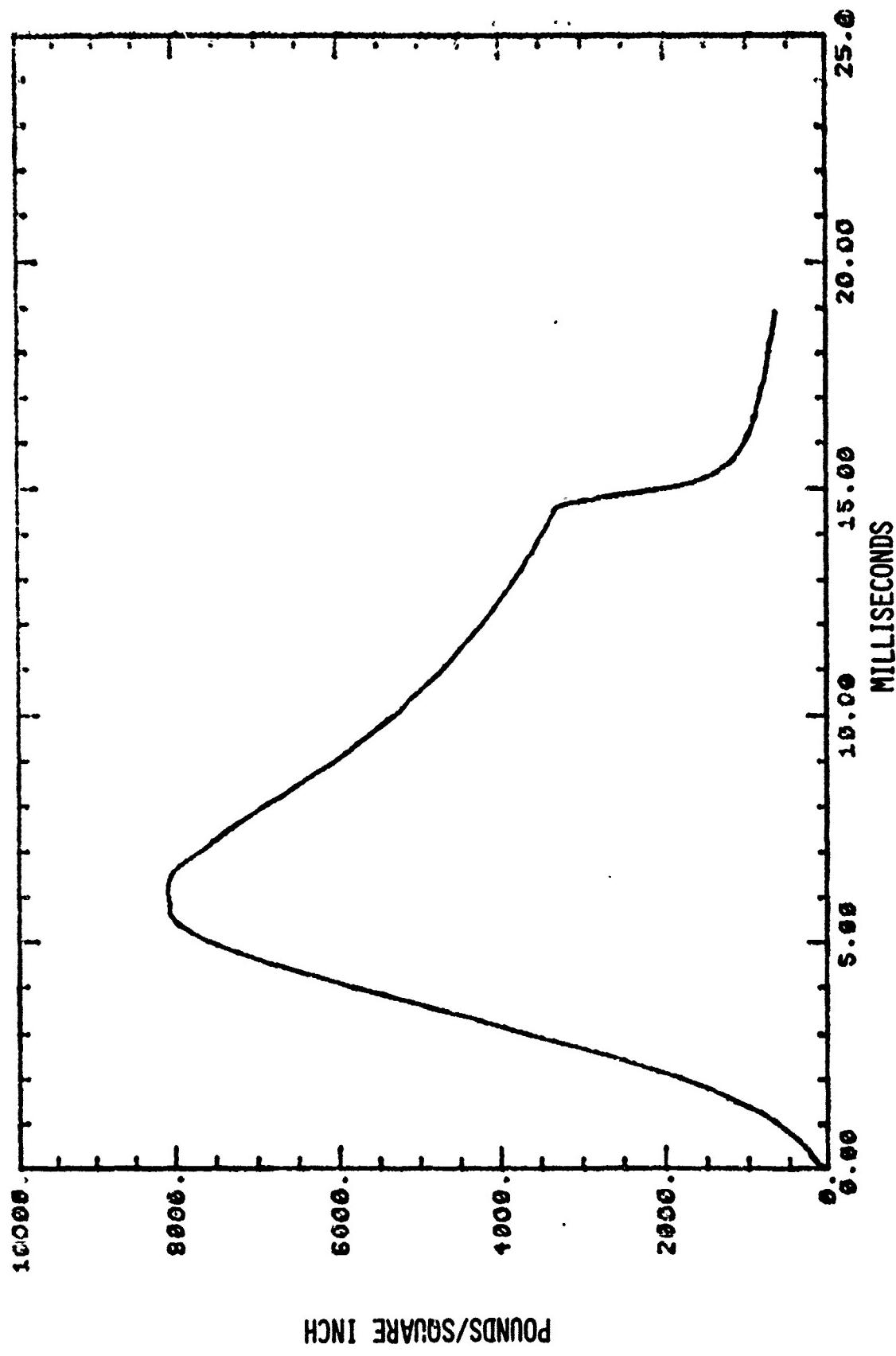


Figure 6 CHAMBER PRESSURE; 5 LB WATER, 5 MM DROP SIZE

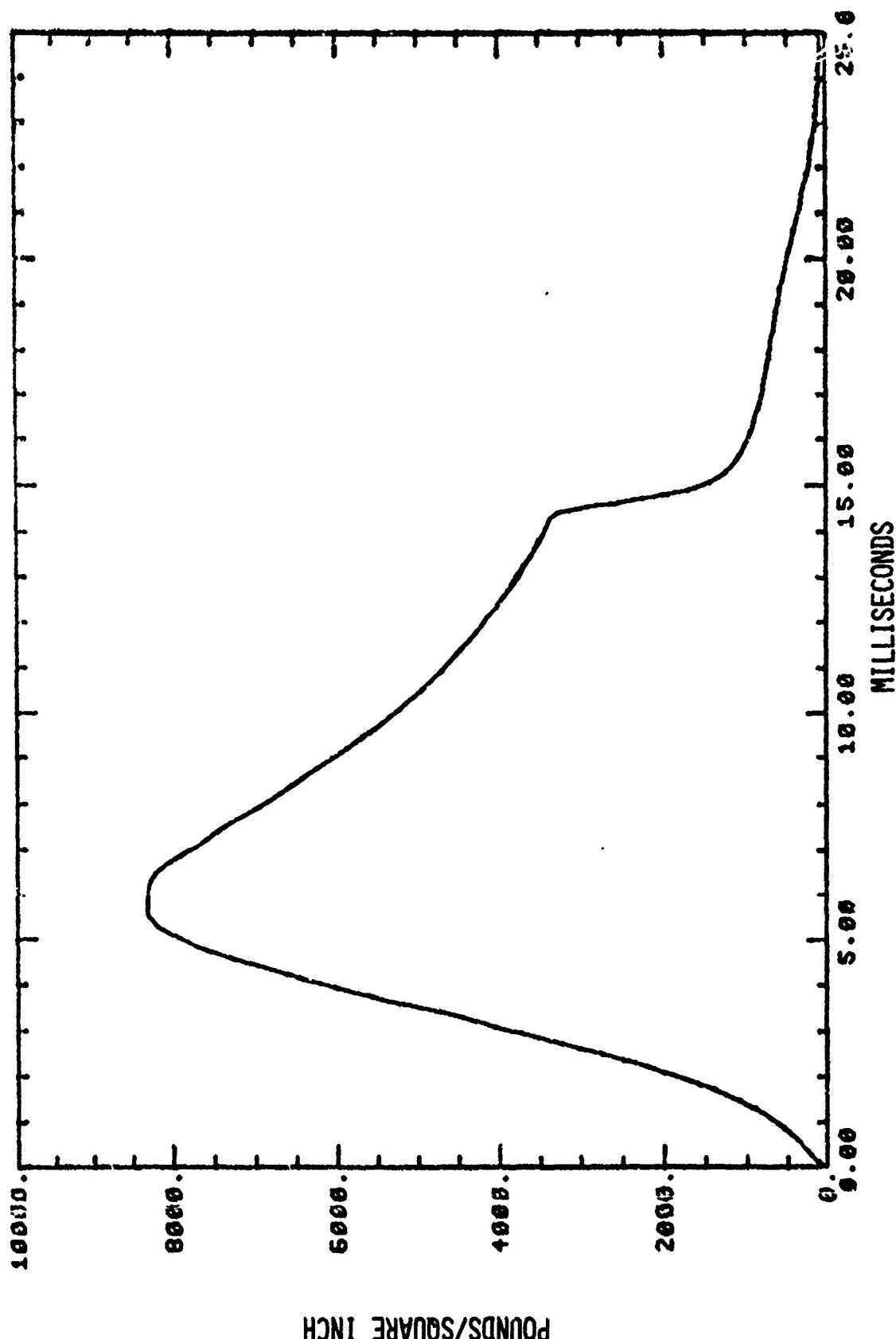


Figure 7 CHAMBER PRESSURE, 5 LB WATER, 1 MM DROP SIZE

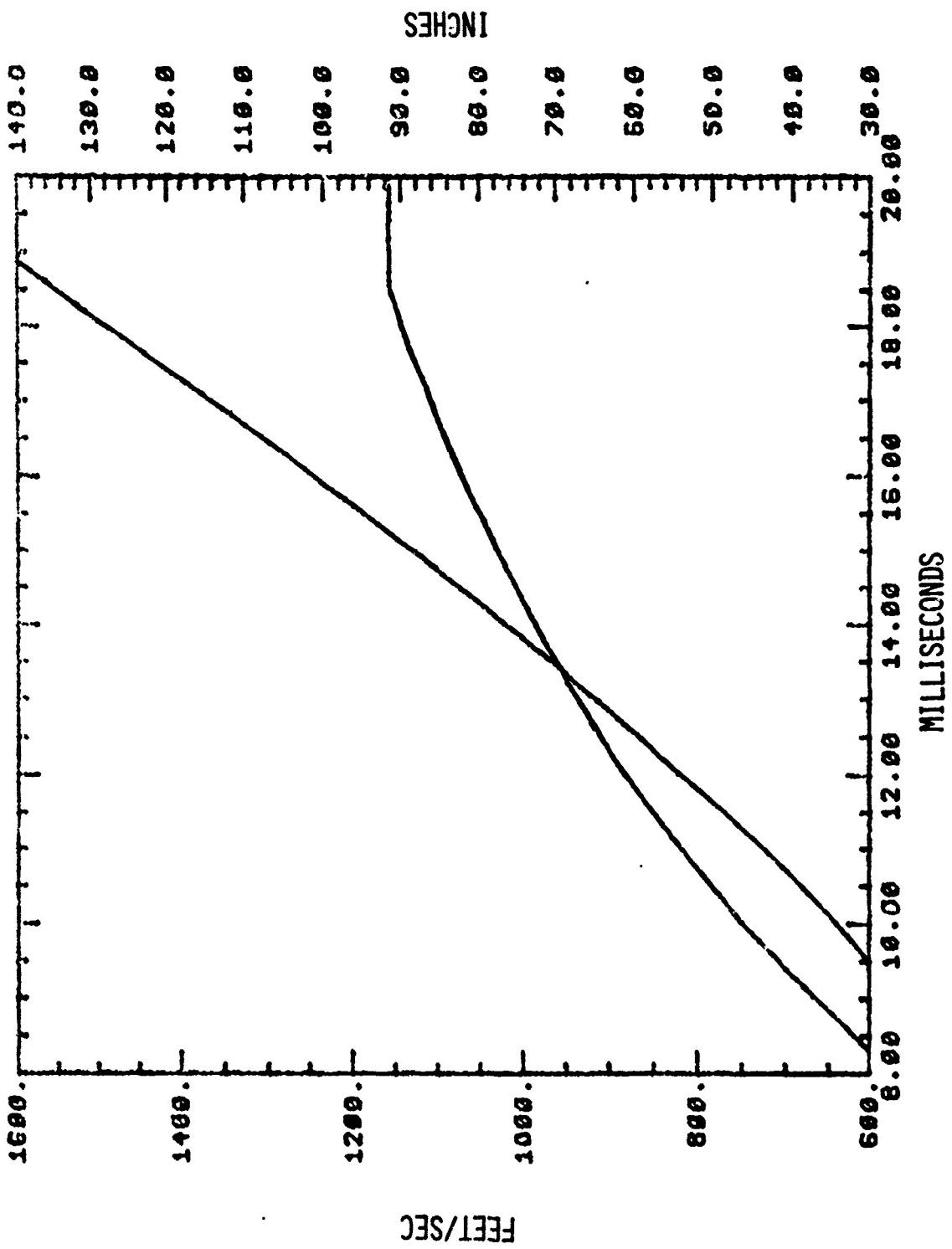


Figure 8 PROJECTILE VELOCITY AND TRAVEL DISTANCE, NO WATER

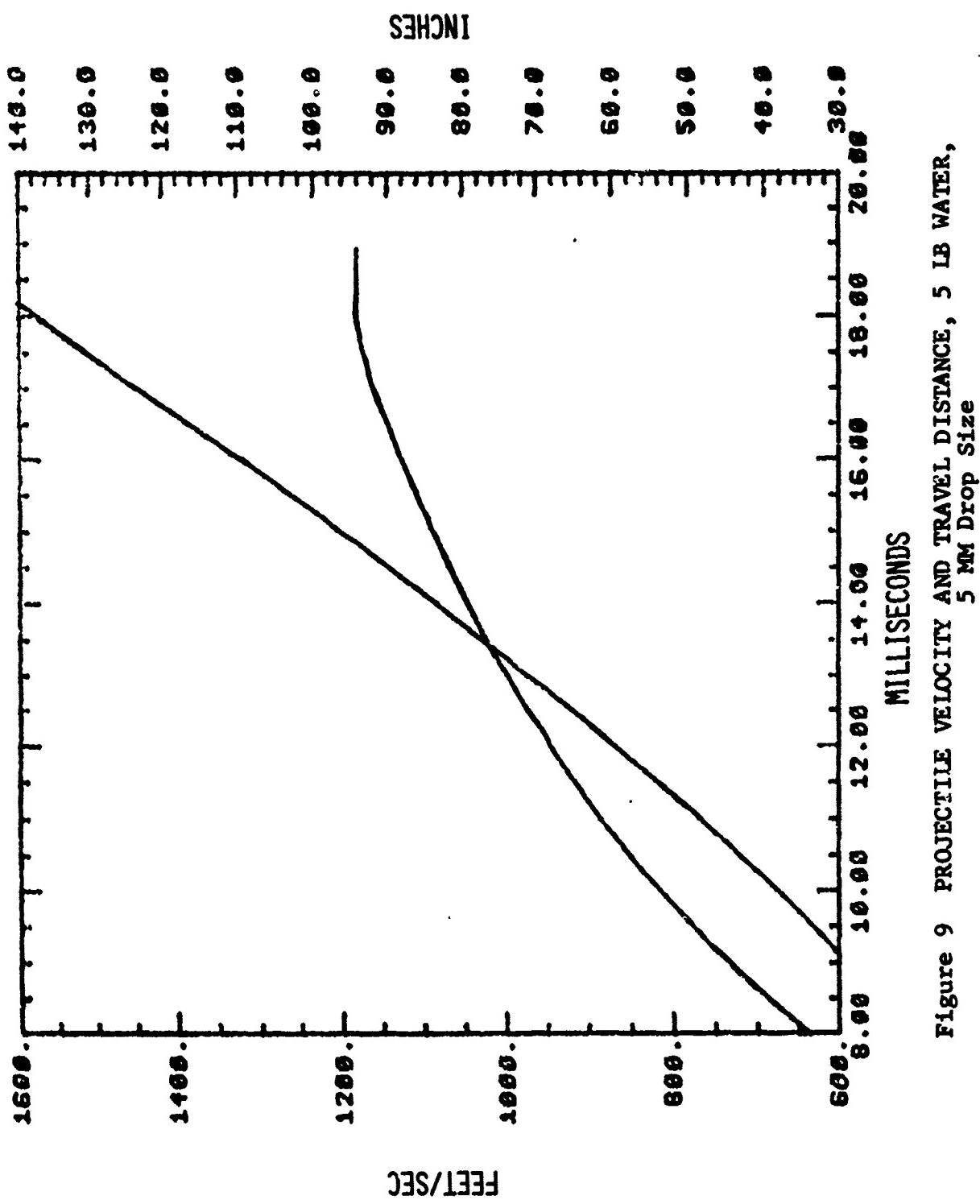


Figure 9 PROJECTILE VELOCITY AND TRAVEL DISTANCE, 5 LB WATER,  
5 MM DROP SIZE

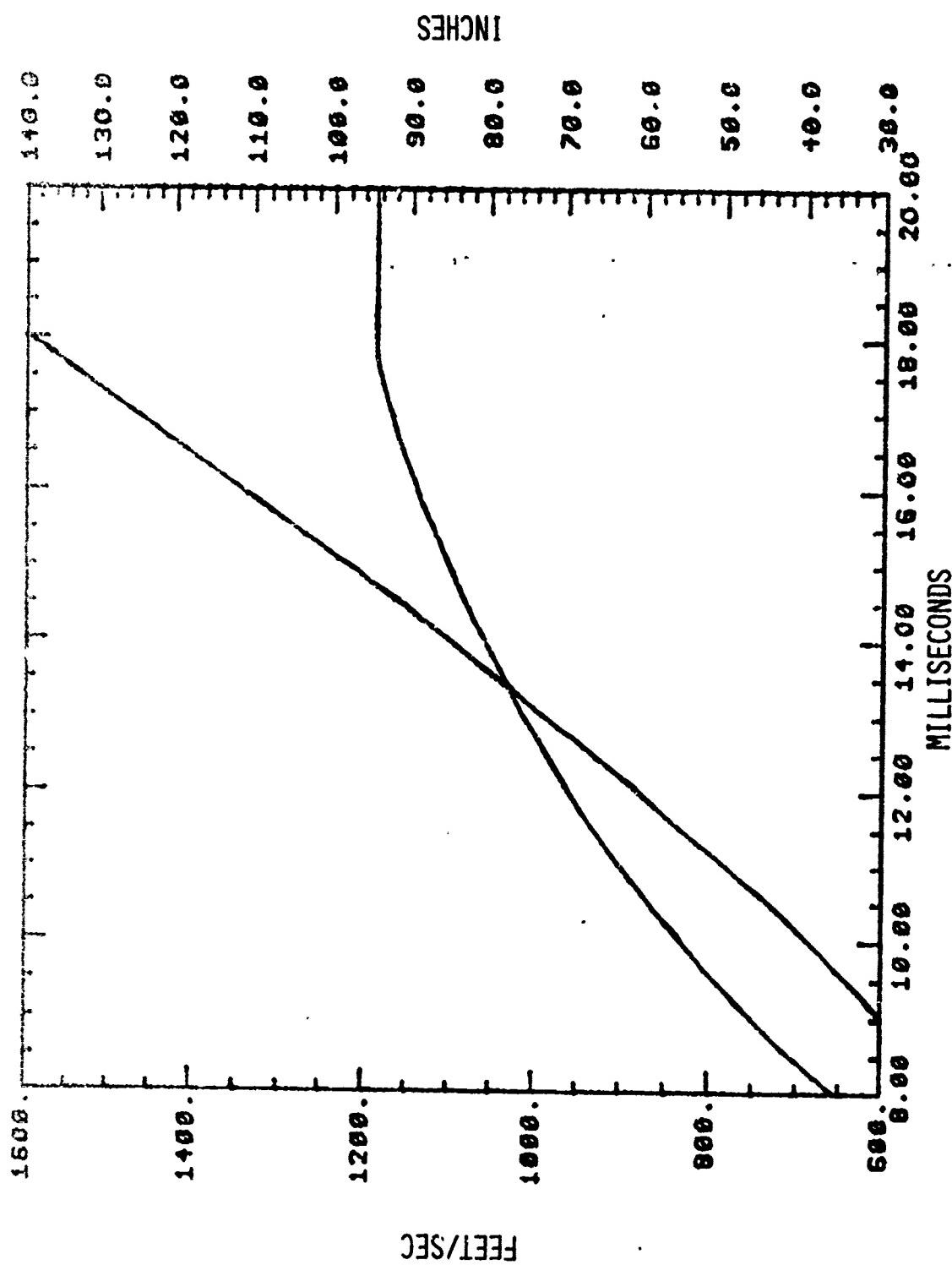


Figure 10 PROJECTILE VELOCITY AND TRAVEL DISTANCE, 5 LB WATER,  
1 MM DROP SIZE

The output of the one-dimensional program was used as an input condition for the two-dimensional program. Early time examples of the spatial pressure distribution are shown in Figs. 11-12. The flow out of the attached cylinder is directed to the right and the cylinder exit is located on the horizontal axis in the center of the smallest contour. As one would expect, the pressure profile is elongated in the direction of flow. For the purpose of evaluating the effect on the blast pressure of water in the cylinder attached to the rifle, the pressure was listed for selected points for each case. The location of these points A-F is indicated in Fig. 13, and the pressure pulse profiles in Figs. 14-16. These pressure pulse profiles show that the peak pressure increases as water is added to the cylinder and the drop size is diminished.

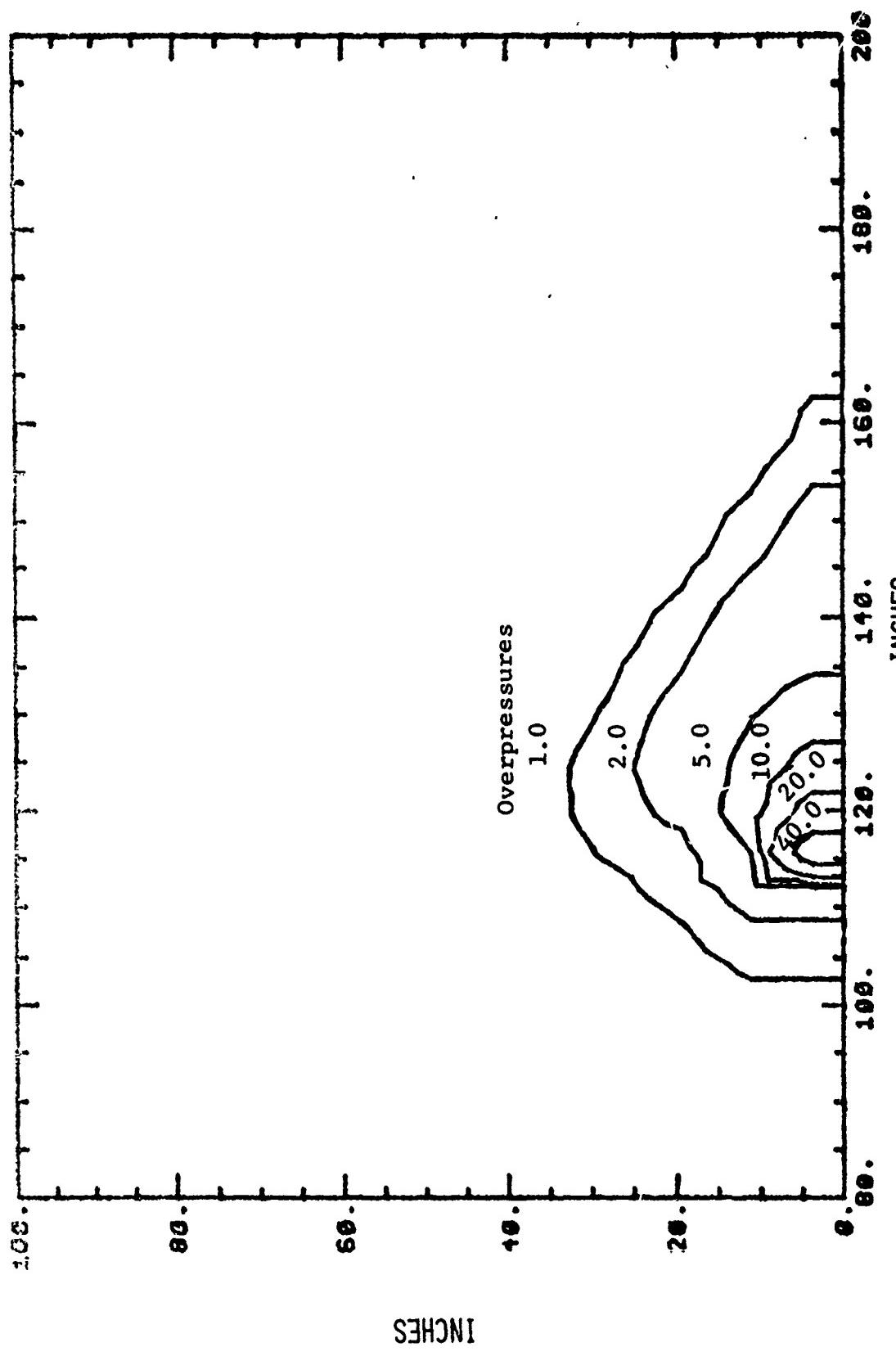


Figure 11 PRESSURE PROFILE CONTOURS, 3.5MSEC AFTER IGNITION, 5 LB WATER  
1 MM DROP SIZE

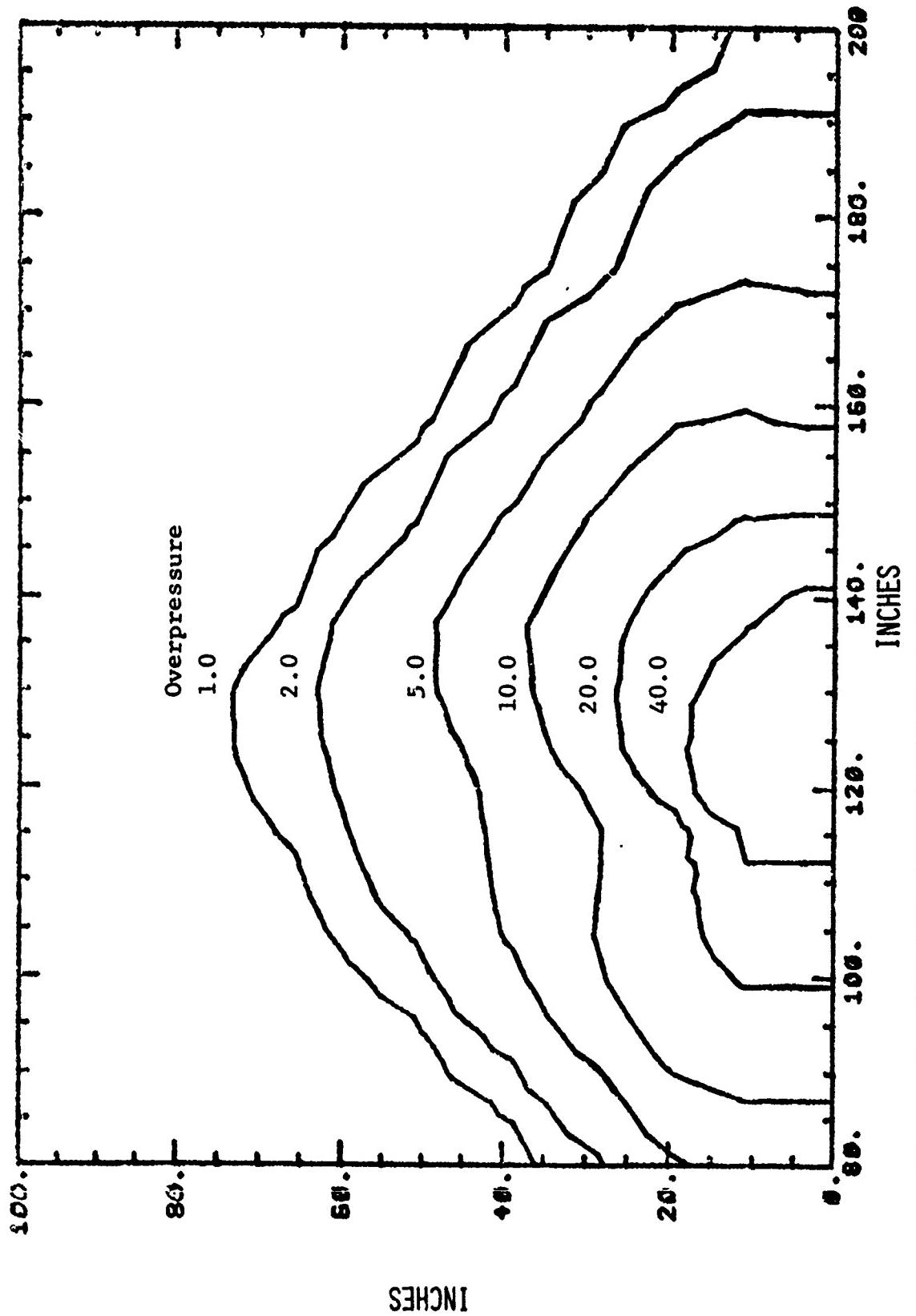


Figure 12 PRESSURE PROFILE CONTOURS, 5.7 MSEC AFTER IGNITION, 5 LB WATER,  
1 MM DROP SIZE

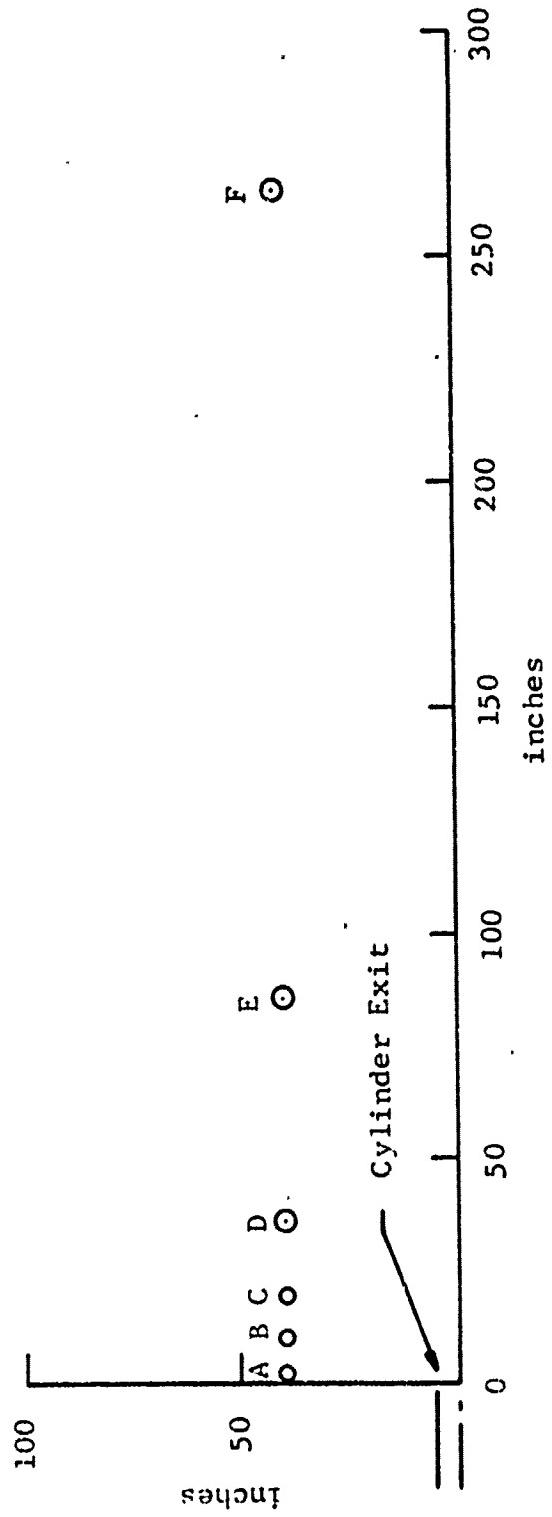


Figure 13 LOCATION OF POINTS IN BLAST FIELD FOR WHICH PRESSURE IS PLOTTED AS A FUNCTION OF TIME

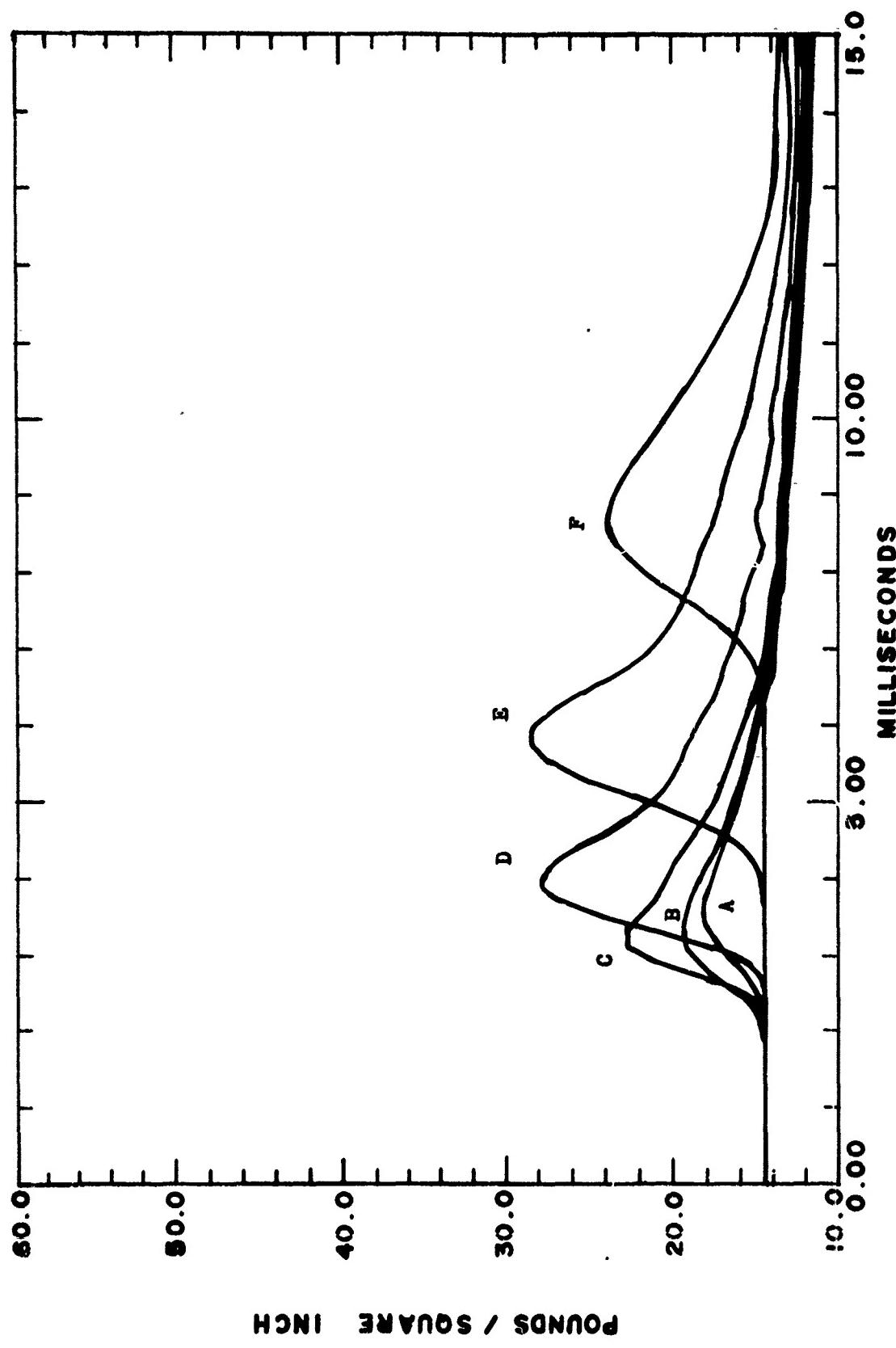


Figure 14. Pressure (static plus dynamic) vs time with no water in the cylinder

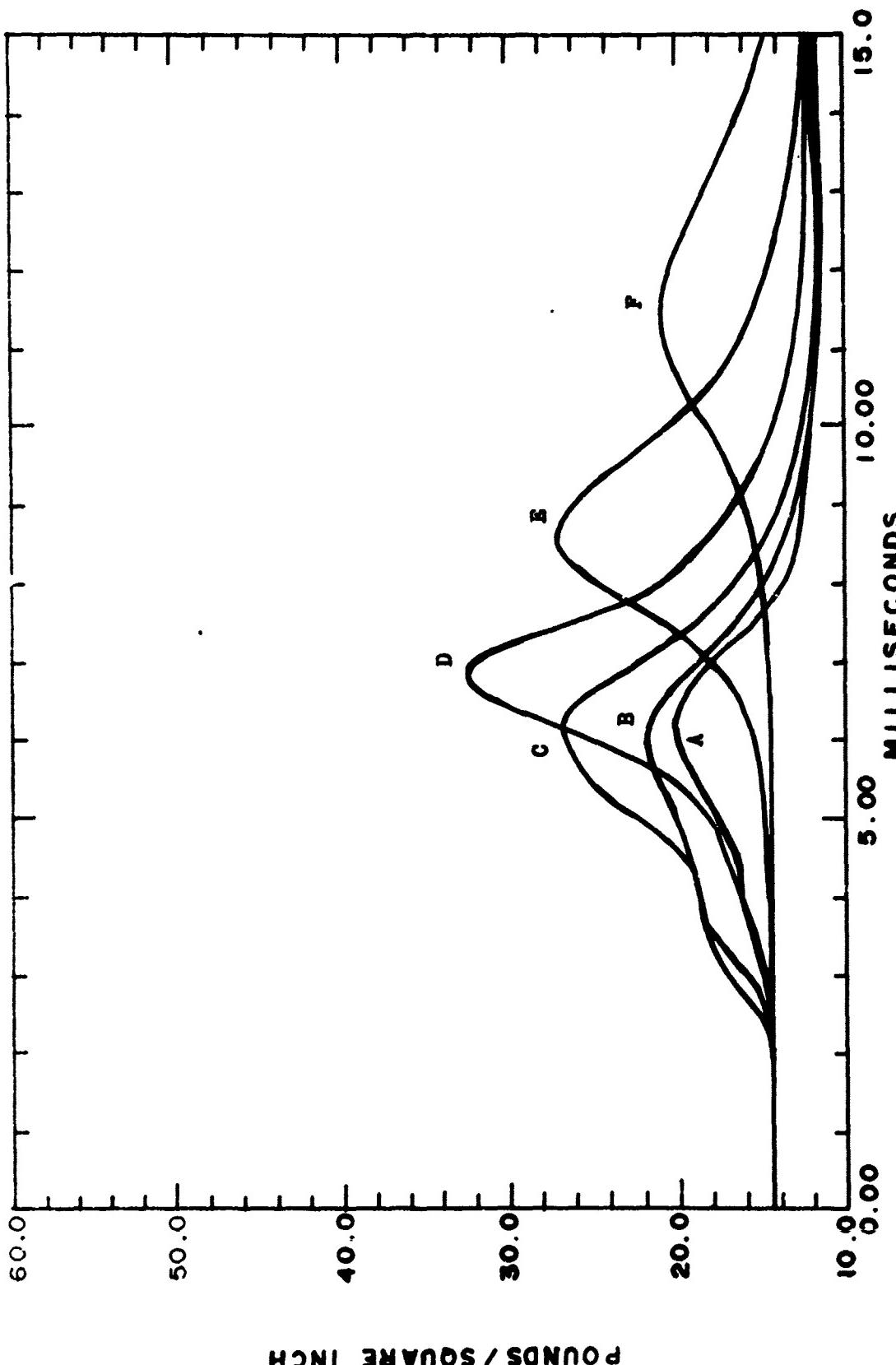
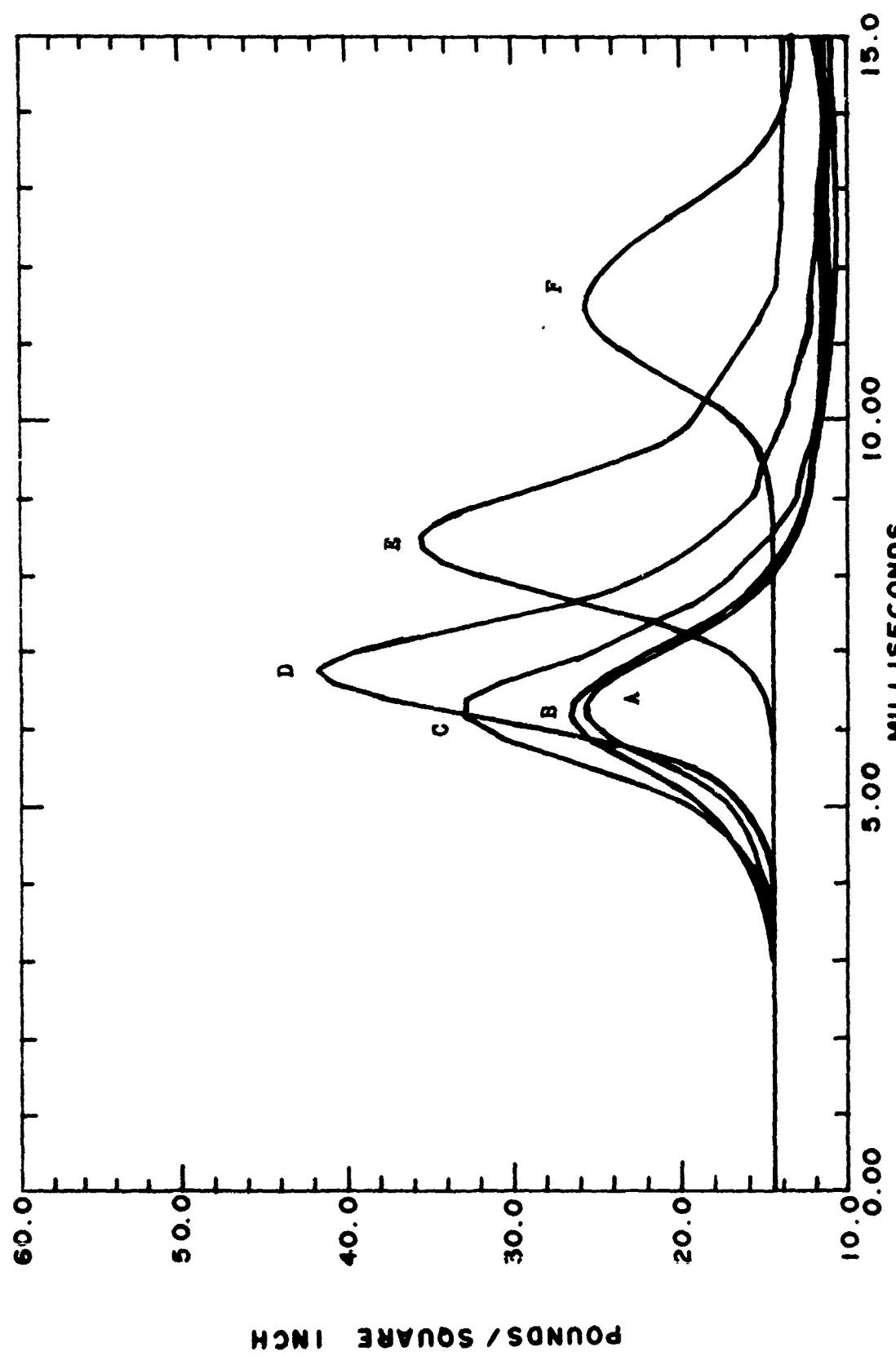


Figure 15 PRESSURE (STATIC PLUS DYNAMIC) VS TIME WITH 5 LB OF WATER IN THE ASSUMED DROP SIZE - 5 MM

Figure 16 PRESSURE (STATIC PLUS DYNAMIC) VS TIME WITH 5 LB OF WATER IN THE  
CUPHOLDER, TOP SIZE, 1 IN.



POUNDS / SQUARE INCH

## 5. SUMMARY OF RESULTS AND CONCLUSIONS

Contrary to the reasons advanced for expecting blast attenuation, the results obtained show that the peak pressure is increased rather than reduced by expelling water. The duration of the pulse is shorter, however, so that the total blast load represented in the pulse may be somewhat reduced. The most probable explanation involves the effect of flow duration and perhaps also the ability of the particles to transfer momentum to the blast field after expulsion from the cylinder.

In the study of the short cylinder concept it was thought that an optimum particle size might exist that would prolong flow duration, thereby reducing the peak blast pressure. It appears, however, that particles of suitable size, on the order of 1 mm, also have a drag-to-weight ratio so large that the momentum absorbed from the propellant gas in the cylinder is given back to the air when the particles emerge. The remaining hope for reducing the blast pressure with a concept involving particle expulsion is to use considerably more water so as to absorb more energy from the propellant gas, or to exploit other phenomena not investigated in this study, such as quenching the gas by the cooling effect of droplet vaporization.

## REFERENCES

1. Taylor, G., "The Formation of a Blast Wave by a Very Intense Explosion," Vol. 201.
2. Soo, S. L., Fluid Dynamics of Multiphase System, Blaudell Publishing Co., (1967).
3. Marble, F. E., "Dynamics of Dusty Gases," Annual Rev. Fluid Mech., Vol. 2, (1970).
4. Baer, P. G. and Bryson, K. R., Tables of Computed Thermodynamics Properties of Military Gun Propellants, BRL Memo. Rept. No. 1338 (Mar. 1961).
5. Perry, J. H., Chemical Engineering Handbook, McGraw-Hill Publishing Co. (1950).
6. McAdams, Heat Transmission, McGraw-Hill Publishing Co. (1954).
7. Gentry, R. A.; Martin, R. E.; and Daly, B. J., "An Eulerian Differencing Method for Unsteady Compressible Flow Problems," Computational Phys., Vol. 1, pp 87-118 (1966).

**APPENDIX A**  
**ONE-DIMENSIONAL GAS PARTICLE FLOW**

ONE DIMENSIONAL GAS PARTICLE FLOW

L1 = MAXIMUM AXIAL NOSE  
 KN = OUTPUT FREQUENCY  
 KP = PLOT FREQUENCY  
 KW = NUMBER OF RUNGE KUTTA STEPS TO BE EXECUTED ON THIS RUN  
 KST = 1 START WITH CONDITIONS AT INSTANT OF IGNITION  
 KST = 2 CONTINUE INTEGRATION WITH CONDITIONS ON A FILE PRODUCED  
 DURING A PREVIOUS RUN  
 KKST = RUNGE KUTTA STEP ON FILE USED FOR STARTING CONDITIONS  
 KS1S = 1 PARTICLE SLIP ACCOUNTED FOR  
 KS1S = 2 NO SLIP IS ASSUMED  
 KS1H = 1 TEMPERATURE DIFFERENCE BETWEEN GAS AND PARTICLES IS  
       ASSUMED TO EXIST AND HEAT TRANSFER IS CALCULATED.  
 KS1H = 2 GAS AND PARTICLES HAVE THE SAME TEMPERATURE  
 KS1K = 1 PARTICLES EVAPORATE  
 KS1K = 2 PARTICLES DO NOT EVAPORATE.  
 FL = ARTIFICIAL VISCOSITY COEFFICIENT  
 ER = ALLOWABLE ERROR LIMIT IN RUNGE KUTTA INTEGRATION  
 RHOP = DENSITY OF PARTICULATE PHASE  
 VISCG = VISCOSITY OF GAS  
 VFMIN = VALUE OF MINIMUM VOID FRACTION WHICH IF EXCEEDED  
 ACTUATES ARTIFICIAL PRESSURE IN PARTICULATE PHASE  
 PDF = FACTOR FOR ARTIFICIAL PRESSURE IN DISPERSED PHASE  
 FJ = MECHANICAL EQUIVALENT OF HEAT  
 CMAX = MAXIMUM ALLOWABLE VALUE FOR TIME STEP LIMITING COEFFICIENTS  
 PD(1) = ARTIFICIAL PRESSURE IN MOMENTUM EQUATION FOR  
       PARTICULATE PHASE  
 Q(1) = ARTIFICIAL VISCOSITY  
 Y(1) = UNBURNED PROPELLANT POUNDS  
 Y(2) = PROJECTILE VELOCITY FT/SEC  
 Y(3) = TRAVEL INCHES  
 Y(4) = IMPULSE POUNDS X SEC  
 Y(5) = IMPULSE X TIME POUND X SEC XX 2  
 FILES  
 8 FYST  
 9 RESTART  
 11 FEX:  
 12 FY52  
 PARAMETER VDC=20C  
 PARAMETER NFKD=1330

MAIN010  
MAIN020  
MAIN030  
MAIN040  
MAIN050  
MAIN060  
MAIN070  
MAIN080  
MAIN090  
MAIN100  
MAIN110  
MAIN120  
MAIN130  
MAIN140  
MAIN150  
MAIN160  
MAIN170  
MAIN180  
MAIN190  
MAIN200  
MAIN210  
MAIN220  
MAIN230  
MAIN240  
MAIN250  
MAIN260  
MAIN270  
MAIN280  
MAIN290  
MAIN300  
MAIN310  
MAIN320  
MAIN330  
MAIN340  
MAIN350  
MAIN360  
MAIN370  
MAIN380  
MAIN390

```

DIMENSION Y(100),X(100),W(100),AE(NRKD),AE(NRKD),AEF(7)
COMMON /NRK/ NZ, NRK, KP, KM, IP1, IP2, XST, KKST, IMW, KSW, KK0,
COMMON /ALR/ IN, K, VHL(INDC), VHR(INDC),
2 NFS, FE, PS, PE, PA, IDO, X83, ZMAX, Z, IR, VHL(INDC), VHR(INDC),
3 FL, RHD, VISC, VFVN, POF, JCMAX, PV1, PV2, PV3, CHARG, PROJ, CHML,
4 WIDTH, CPP, EBL, FORCE, DSCPS, IS, CYCL, A, CCPCTN, AC, VPROJ, ZPROJ, PB,
5 FC(NDK,7), CS(NDK,7), EG(NDK), FM(NDK), UG(NDK),
6 UP(NDK), AC(NDK), V(NDK), V3(NDK), XC(9), RHOG(NDK), PG(NDK),
7 PR(NDK), DP(NDK), DF(NDK,7), G(NDK,7), Q(NDK), Z(NDK), ZB(NDK)
4 , GAC(NDK), GCA(NDK), GE(NDK), VFA(NDK), FW(NDK)
CCINON, / MU / KSW, KSWH, KSWI
COMMON /NC/ NZ, Z(7), ZWC(7), IZ(7), ZW(7), IEX
4 CONTINUE
5 READ(5,10) IN, K, KP, KM, KST, KKST, KSJS, KSHH, KSHM
101 FORMAT(8I10/1I0)
      WRITE(6,102) IN, K, KP, KM, KST, KKST, KSJS, KSHH, KSHM
102 FORMAT(1I1,4X,2I1, 1H=,15,
2          3X,2HK4, 1H=,15,

```

A-3

ONE CHINESE NATIONAL PARTICLE FROM

```

5    *1CX,2-3L   *1HZ,   *14,6, 7H INCHES
6    *1CX,4-3DRE  *14z,   *14,6, 3H MM
7    *1CX,5-VCHA4  *1HZ,   *14,6,13H CUBIC INCHES
8    *1CX,4-CVA1   *1HZ,   *14,6, 8H DEGREES
9    *1CX,4-CVA2   *1HZ,   *14,6, 8H DEGREES
A    *1CX,2-FRN   *1HZ,   *14,6, 7H INCHES
B    *1CX,3-DTM   *1HZ,   *14,6, 7H INCHES
C    *1CX,4-DCXC  *1HZ,   *14,6, 7H INCHES
D    *1CX,3-4EVL  *1HZ,   *14,6, 7H INCHES
E    *1CX,4-FGNT   *14z,   *14,6, 7H POUNDS

KKZ=-1
I=4*7*1M+5
CALL CALXC (C\A1,C\A2,RN,DTM,DEXC,BL,BORE,VCHAMB,ENL,XC,XBS)
WRITE (6,108) (1H ,10X,2H15,12,3X,6HX(1),,1PE14.6)
108 FORMAT (1H / (1H ,10X,2H15,12,3X,6HX(1),,1PE14.6))
CALL ZSPACE
CALL TDFZB(ZPL1*2,54,IPL1)
MAIN1140
MAIN1130
MAIN1120
MAIN1110
MAIN1100
MAIN1090
MAIN1080
MAIN1070
MAIN1060
MAIN1050
MAIN1040
MAIN1030
MAIN1020
MAIN1010
MAIN1000
MAIN990
MAIN980
MAIN970

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

CALL ICFZB(ZPL2*2,54,IPL2)
IPL1=IPL1-1
CALL IOFZ(-ENL*2,54,1EX)
IEX=IEEX+1
      WRITE(6,111) 12,Z3,ZMAX,ZPL1,ZPL2,IPL2,1EX
111  FORMAT(1H0,5X,3*13*,16,5X,3H2*,1PE12.5,5X,5HZWAX,E12.5,5X,
      2 5HZPL1*,E12.5,5X,5HZPL2*,E12.5, / 1H ,5X,5HPL1*,16,5X,
      3 5HPL2*,16,5X,4*IEX=,16)
      WRITE(6,137) (I,2(I),2B(I),A(I),V8(I),V(1),V8(I),I=1,1H)
137  FCRWAT(1+1,5X,1H10X,1H2,16X,2-I25) 17X,1H4,18X,2HAB,17X,1H,
      1 1AX,2*V8 / (1H ,16*1PE19.6,5E19.6)
      READ(5,112) VZW,ZM(I),I=1,7)
112  FORMAT(5,112)VZW,ZM(I),I=1,7)
      DC 5 I=1,2,
      Z2=2.54*(XC(3)-Z*(1))
      ZXC(I)=Z2
      CALL IOFZ(22,11)
      I2A(I)=11
      WRITE(6,113) (1,12M(I),2M(I),1,2WC(I),I=1,N2W)
113  FORMAT(1H0,14X,1M10,7X,3H124,8X,2H24,12X,3HZWC /
      2 61H ,10X,2110,1DE14.5,E14.5)
      DSCPSS=455.59*980.,516/(2,54**2)
      CCPC1N=2.54**3
      AP=2,3*CH4*RC*453,53/(1.6**10TH*(2,54**3))
      AC=0,25*3.141593*((80RE/25,4)**2)
      Z2=0,5*(XC(3)+XC(4))**2,54
      CALL ICFZB(22,NFS)
      CALL IOFZB(2.54*XC(7),NFE)
      NPS=NFE
      NFE=NFE+1
      CHANL=VCHA*4E*(2,54**3)/(0.25*3.141593*(0,1*B0RE)**2)
      ZZ=Z(NPS)+CHANL+2,54*4.0
      CALL IOFZ(ZZ,NFE)
      WRITE(6,139) NFS,Z(NPS),NFE,Z(NPS),NFE,Z(NFE)
139  FORMAT(1H0, 9X,4HNF,3,16,5X,1PE14.6,
      2 10X,4HNPS*,16,5X, / 10X,4HNPE*,16,5X,
      3 1CX,4HNPE*,16,5X, / E14.6,
      4 FN:=3.141593/6,C*RHO*(CP0/1G)**3)
      MAIN150
      MAIN149
      MAIN148
      MAIN147
      MAIN146
      MAIN145
      MAIN144
      MAIN143
      MAIN142
      MAIN141
      MAIN140
      MAIN139
      MAIN138
      MAIN137
      MAIN136
      MAIN135
      MAIN134
      MAIN133
      MAIN132
      MAIN131
      MAIN130
      MAIN129
      MAIN128
      MAIN127
      MAIN126
      MAIN125
      MAIN124
      MAIN123
      MAIN122
      MAIN121
      MAIN120
      MAIN119
      MAIN118
      MAIN117
      MAIN116
      MAIN115
      MAIN114
      MAIN113
      MAIN112
      MAIN111
      MAIN110
      MAIN109
      MAIN108
      MAIN107
      MAIN106
      MAIN105
      MAIN104
      MAIN103
      MAIN102
      MAIN101
      MAIN100
      MAIN99
      MAIN98
      MAIN97
      MAIN96
      MAIN95
      MAIN94
      MAIN93
      MAIN92
      MAIN91
      MAIN90
      MAIN89
      MAIN88
      MAIN87
      MAIN86
      MAIN85
      MAIN84
      MAIN83
      MAIN82
      MAIN81
      MAIN80
      MAIN79
      MAIN78
      MAIN77
      MAIN76
      MAIN75
      MAIN74
      MAIN73
      MAIN72
      MAIN71
      MAIN70
      MAIN69
      MAIN68
      MAIN67
      MAIN66
      MAIN65
      MAIN64
      MAIN63
      MAIN62
      MAIN61
      MAIN60
      MAIN59
      MAIN58
      MAIN57
      MAIN56
      MAIN55
      MAIN54
      MAIN53
      MAIN52
      MAIN51
      MAIN50
      MAIN49
      MAIN48
      MAIN47
      MAIN46
      MAIN45
      MAIN44
      MAIN43
      MAIN42
      MAIN41
      MAIN40
      MAIN39
      MAIN38
      MAIN37
      MAIN36
      MAIN35
      MAIN34
      MAIN33
      MAIN32
      MAIN31
      MAIN30
      MAIN29
      MAIN28
      MAIN27
      MAIN26
      MAIN25
      MAIN24
      MAIN23
      MAIN22
      MAIN21
      MAIN20
      MAIN19
      MAIN18
      MAIN17
      MAIN16
      MAIN15
      MAIN14
      MAIN13
      MAIN12
      MAIN11
      MAIN10
      MAIN9
      MAIN8
      MAIN7
      MAIN6
      MAIN5
      MAIN4
      MAIN3
      MAIN2
      MAIN1
      MAIN0

```

```

CL=SHOP*(1.0-VFNI)
FLE\=H20*453.59/(CL*0.25*3.141593*(DEXC*2.54**2)
ZL=2.54*XC(4)-FLE\Y
CALL ICEZ(ZL,54,XC;4),12)
CALL IOZ(ZL,11)
I1=11-1
I2=12-1
VQLP=(25(I2)-28(I1-1))*0.25*3.141593*((DEXC*2.54)**2)
MAIN1540
MAIN1550
MAIN1560
MAIN1570
MAIN1580
MAIN1590
MAIN1600
MAIN1610
MAIN1620
MAIN1630
MAIN1640
MAIN1650
MAIN1660
MAIN1670
MAIN1680
MAIN1690
MAIN1700
MAIN1710
CL=AMAL1(CL,1,3,E-10)
FNSR=CL/FX
VF=1.0-CL/RHOP
CGS=VF*G*CC10*94
IF (KST-1) 7,2,7
2 Y(1)=CHARGE
  DC3 I=2,5
3 Y(1)=0.0
  FNPN1=FNPN1+36-3

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

FNPV1=MAX1(FNPV1,1.0E-15/FMN)
ZP=CHAML+2.54*(4.0+XC(7))
CALL IOUFZ(ZP,IPRJ)
VV=ABC(IPRJ)*(ZP-Z3(IPRJ-1))
IMX=IPRJ
IPO=1
KS=1
DO 11 I=1,15
  IF (I-IPRJ) 15,14,15
  14 VVV=VV
  15 VVV=V(I)
  20 CONTINUE
  F(I,1)=0.0019694*VV
  F(I,3)=FNPV1*VV
  F(I,5)=FMN*FNPV1*VV
  F(I,4)=293.0*F(I,5)
  F(I,2)=F(I,1)*(-1.145E3)+F(I,4)
  F(I,6)=0.0
  F(I,7)=0.0
  11 DC 12 I=1,12
  F(I,1)=CGG*V(I)
  F(I,3)=FNPV1*V(I)
  F(I,5)=FNPV1*V(I)
  F(I,4)=F(I,5)*296.0
  12 F(I,2)=F(I,1)*(-1.145E3)+F(I,4)
  DT=0.00001
  12 DT=0.00001
  7 CONTINUE
  DO 9 I=1,5
    9 RE(I)=EZ*CHARG
    AE(1)=EZ*CHARG
    AE(2)=EZ*2000.0
    AE(3)=EZ*140.0
    AE(4)=EZ*2003.0
    AE(5)=AE(4)
    AEF(1)=EZ*0.1
    AEF(2)=AEF(1)*1000.0
    AEF(3)=EZ*FNPV1

```

AEF(5)=EZ\*FM\*\*FNP  
AEF(4)=AEF(5)\*5CJ.0  
AEF(5)=AEF(1)\*40000.0  
AEF(7)=AEF(5)\*40000.0  
L=5  
DO 6 I=1,11  
CC 6 K=1,7  
L=L+1  
RE(L)=ER  
AE(L)=AEF(K)\*V(L)  
V(L)=F(L,K)  
RE(1)=D 6  
RE(1)=D 9  
RE(1)=D 16  
REWIND 11  
IF (KST-2) 17,16,17  
16 CC,T,I\*UE  
OC 13 LL=1,1000

MAIN2110  
MAIN2120  
MAIN2130  
MAIN2140  
MAIN2150  
MAIN2160  
MAIN2170  
MAIN2180  
MAIN2190  
MAIN2200  
MAIN2210  
MAIN2220  
MAIN2230  
MAIN2240  
MAIN2250  
MAIN2260  
MAIN2270  
MAIN2280

ONE DIMENSIONAL GAS PARTICLE FLOW

```
MAIN220
MAIN230
MAIN2310
MAIN2320
MAIN2330
MAIN2340
MAIN2350
MAIN2360
MAIN2370
MAIN2380
MAIN2390
MAIN2400
MAIN2410
MAIN2420
MAIN2430
MAIN2440
MAIN2450
MAIN2460
MAIN2470
MAIN2480
MAIN2490
MAIN2500

READ (5) KK,T,DT,IPRJ,IMW,KSW,(Y(I)),I=1,IRK)
READ (1C) K9
IF (KK-KKST) 18,19,19
19 CONTINUE
12 CC,TINE
DD 2 LL=1,10000
READ (8) KK1
READ (11) KK3
IF (KK1-KK3) 6,13,13
13 CONTINUE
14 KK=KK-1
IPS=IPRJ
17 CONTINUE
EXTERNAL DEFIV,CNTL
CALL RK2 (DEFIV,CNTL,Y,DY,AE,AE,T,DT,IRK,2,0E6)
PE*IND 8
RE*IND 9
RE*IND 10
RE*IND 11
CC TO 1
END
```

ONE-DIMENSIONAL GAS PARTICLE FLOW

A-11

Reproduced from  
best available copy.

11 FORCE=FORCE+PG(1)\*(AB(1-1)-AB(1))  
FORCE=FORCE/(780.616\*453.59)  
DY(4)=FORCE  
DY(5)=EV(4)  
RETURN  
END

DER10400  
DER10410  
DER10420  
DER10430  
DER10440  
DER10450

## **Preceding page blank**

```

CG(1)=F(1,1)/V(1)
FN(1)=2*X1(FXN,F(1,3))/V(1)
FXV(1)=2*AX1(FMN,F(1,5))/V(1)
FN(1)=FMV(1)/FN(1)
? CONTINUE
  GO TO 1,32,KSW
 4: CG(IPRJ)=F(IPRJ,1)/VV
FN(IPRJ)=ANLYT(FN,F(IPRJ,3))/VV
FXV(IPRJ)=ANLYX1(FN,F(IPRJ,5))/VV
37 CONTINUE
  DC 3 I=2,1w
CG=(VN((1)*CG((1+1)*VN((1+1)*CG((1+1))/VN(1))
FN5=(VN((1)*VN((1+1)*VN((1+1)*VN((1+1))/VN(1))
GTG(42,33),KSPS
 42 CONTINUE
UP(1)=F(1,7)/(FN3*VB(1))
UG(1)=(F(1,6)-F(1,7))/(CGB*VB(1))
GO TO 3

```

COURT OF APPEALS FOR THE NINTH CIRCUIT

A-15

Reproduced from  
best available copy.

GO TO 902

C FLAG EG(1)=(SCRT((W2-W4)-(0-W1-W3)-W2)/(2.0-W3))

24 WTST=W2-W2-4.0-W12.5

WTST1=MAX1(WTST,0)

EG(1)=(SCRT(WTST1)-2)/(2.0-W3)

1E (WTST) 901,902,902  
901 WRITE (6,901),S,A40,WTST,W1,W2,W3,F1,F2,F3  
901 FORMAT (1H,5X,12DG,E21) WARNING,5X,241=,15,5X,2HSS,1PE12,5,5X,  
2412,5,5X,3H,3=E12,5,5X,3H,1=,E12,5,5X,3H,2=,  
312,5,5X,3H,3=E12,5,5X,3H,1=,E12,5,5X,3H,2=,  
434F5E,E12,5,5X,3H,3=E12,5,5X,3H,1=,E12,5,5X,

902 CALL T0EAR (EG(1),RHG,TP(1))

7 CONTINUE

7 EG(1)=2.0\*EG(2)-EG(3)

TP(1)=2.0\*TP(2)-TP(3)



```
2 -(PG(I+1)-PG(1)) *AB(I) *FMVB/R400
DF(I,7)=DF(I,7)+F(I,7)*DC(I,7)*V5(I)
GC(TD,13)
21 CO,TINUE
DF(I,7)=C.
13 CO,TINUE
DC(1,4,I=1,IMAX1)
IM1=I-1
IM1=MAX0(IM1,1)
UB=0.5*(UP(I)+UP(I+1))
CALL LOGFI(CUB,L)
CALL LOGFI(CUB,L)
C(I,7)=A(I,F(I,V(I))+UP(I))
G(I,6)=G(I,7)
UB=0.5*(UG(I)+UG(I+1))
CALL LOGFI(UB,L)
G(I,6)=G(I,6)
CALL LOGFI(UP(I),L)
I+=1
```

```
DER11540
DER11550
DER11560
DER11570
DER11580
DER11590
DER11600
DER11610
DER11620
DER11630
DER11640
DER11650
DER11660
DER11670
VER11680
VER11690
DER11700
DER11710
```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

IL=M1*NP1*NP1*IL
ILM1=IL-1
ILW1=ILM1-1
ILW2=WAKO(ILM1-1)*FNC(IL)
G(1,3)=A3(1)*JP(1)*FNC(IL)
G(1,5)=A5(1)*JP(1)*FMV(IL)
G(1,4)=A4(1)*JP(1)*FMV(IL)*CPB*T(IL)
G(1,2)=G(1,4)
2+4*(G(1,4)*JP(1)*FMV(IL)*(EXPA(IL)+EXPA(IL)+EXPA(IL))/FJ)
C4761 CLOSEU ((HIG(1,1),L)
L=L+1
LMAX=A2*(LMAX-1)
LMAX=LMAX-1
LW1=LMAX-1
LW2=A2*(LMAX-1)
PR=0.0
N0.5 IN I=NPS,NEC
51. PR=0.0+PR(1)
52. P32P1/EL34T(VPE-NPS+1)
P32P2/DSCP1
EE=YAE/CHARG
PC=AMAX1(230,C,P5)
FR=0.00186*(P5*0.83)
DY=0.-6.88*2.6*CPC1/A/453.59
DER11720
DER11730
DER11740
DER11750
DER11760
DER11770
DER11780
DER11790
DER11800
DER11810
DER11820
DER11830
DER11840
DER11850
DER11860
DER11870
DER11880
DER11890
DER11900
DER11910
DER11920
DER11930
DER11940
DER11950
DER11960
DER11970
DER11980
DER11990
DER12000
DER12010
DER12020
DER12030
DER12040
DER12050
DER12060
DER12070
DER12080
DER12090
CER12100

201 DVCT=0.0
202 IF (ABS(EE)-0.01) 203,204,202
203 DVCT=DYD1*EE/5.01
204 CON1UE
205 DMDT=-MDOT*453.59/(A(NPE)*(ZB(VPE)-ZB(NPS-1)))
DO 18 I=2,1MW
GO TO 40 (48,44),K6N
48 IF (I-IPRJ) 44,43,44
43 VVV=VV
45 GO TO 45
46 VVV=VV

```

```

45 CONTINUE
  DF(I,1)=-{G(I,1)-G(I-1,1)}
  IF(I-NPS)17,15,15
15  IF(I-NPE)16,16,17
16  DF(I,1)=DF(I,1)+N4DT*VVV
17  DF(I,2)=-(G(I,2)-G(I-1,2))
18  DF(I,3)=-(G(I,3)-G(I-1,3))
19  DF(I,4)=-(G(I,4)-G(I-1,4))
20  DF(I,5)=-(G(I,5)-G(I-1,5))
21  DF(I,6)=DF(I,6)-{(G(I+1,6)-G(I,6))
22  DF(I,7)=DF(I,7)-(G(I+1,7)-G(I,7))
23  GO TO (37,46),KSW+
24  CONTINUE
25  DU=0,5*(UP(I)-UG(I)+UP(I-1)-UG(I-1))
26  RE=DP(I)*RHOG(I)*ABS(DU)/VISCG
27  REP6=ROOT(IRE,S)
28  REP6=REP6*REP6*REP6
29  FNU=2.0+C.34+C.89*REP6
30

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

DER12290
DER12310
DER12320
DER12330
DER12340
DER12350
DER12360
DER12370
DER12380
DER12390
DER12400
DER12410
DER12420
DER12430
DER12440
DER12450
DER12460
DER12470
DER12480
DER12490
DER12500
DER12510
DER12520
DER12530
DER12540
DER12550
DER12560
DER12570
DER12580
DER12590
DER12600
DER12610
DER12620
DER12630
DER12640
DER12650
DER12660
DER12670

45 QC=0.0
46 GE=0.0
47 DF(1,4)=0.0
48 DC(1)=QC
49 GE(1)=QE
50 CONTINUE
51 3EA(1)=0.0
52 3EA(14)=QEAC(14)
53 DO 22 I=2,1M
54 GO TO (26,27),KSW
55 26 DF(1,7)=DF(1,7)-(3EA(1)*FNC(1)+VH(1)+3EA(1+1)*FNC(1+1)+VH(1+1))
56 27 DF(1,7)=P(1)/560.0
57 GO TO 22
58 CONTINUE
59 C FLAG
60 PV=AMINV(PV,760,0)
61 PV=14.7*(PV/760.0)*OSCHSI
62 DMDDT=3.141593*GX*(DP(1)*0.2)*(2V-0.19*PC(1))
63 DMDDT=MAX1(DMDDT,3,0)
64 GO TO 40
65 DMDDT=0.0
66 CONTINUE
67 DF(1,1)=DF(1,1)+DMDDT*F(1,3)
68 GE=3DMDDT*560.0
69 DF(1,4)=DF(1,4)-(2MDDT*TP(1)*CP+QC+3E)*F(1,3)
70 DF(1,5)=DF(1,5)-DMDDT*F(1,3)
71 GO TO 47
72 3EA(1)=0.0
73 3EA(14)=QEAC(14)
74 DO 22 I=2,1M
75 GO TO (26,27),KSW
76 26 DF(1,7)=DF(1,7)-(3EA(1)*FNC(1)+VH(1)+3EA(1+1)*FNC(1+1)+VH(1+1))
77 27 DF(1,7)=0.0
78 CONTINUE
79 C FNU=0.25*VISCC/(0.7*DP(1))
80 QC=FNU*VISCC/(DP(1)*0.7)
81 GO TO (3A,39),KSW
82 3A CONTINUE
83 PV=PVL-PV2/((TP(1)-273.0+PV3)
84 PV=LAVINV(PVL,30,0)
85 PV=EXP(PVL*2.302585)

```

```
DER12660  
DER12690  
VER12700  
DER12710  
VER12720  
DER12730  
VER12740  
DER12750  
DER12760  
  
DO 21 K=1,7  
21 DF(1,K)=0,0  
    GO TO (19,20),KSM  
19 I=IPRJ  
    DF(I,6)=0,0  
    DF(I,7)=0,0  
    CONTINUE  
20 RETURN  
END
```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE CNTRL (Y,DY,DT,T,NT,RY)
PARAMETER NDC=20C
PARAMETER NRKD=18C0
DIMENSION Y(NRKD),DY(NRKD)
COMMON /ALL/ IX,K,KP,KM,IP1,IPL1,IPL2,KST,KKST,IMW,KSW,KKO,
NFS,NFE,NPE,IPRJ,IP0,XBB,ZMAX,ZR,IR,YH(NDC),VHR(NDC),
FL,RHCP,YISCG,VF1IN,BUFFFJ,CMAX,PV1,PV2,PV3,CHARG,PROJ,CHAML,
WIDTH,CPP,BL,FORCE,DSCP51,BR,DXJT,AC,CCPCIN,AC,VPROJ,ZPROJ,PB,
FC(NDC,7),CG(NDC),EG(NDC),FN(NDC),TP(NDC),FM(NDC),UG(NDC),
UP(NDC),A(NDC),AB(NDC),V(NDC),V3(NDC),XC(9),RHOG(NDC),
PC(NDC),DP(NDC),GC(NDC),DF(NDC,7),G(NDC,7),Q(NDC),
TG(NDC),QCA(NDC),DEA(NDC),VFA(NDC),FMV(NDC),
COMMON /NRKC/ NRK
COMMON /MC/ NZ4,Z,(7),ZWC(7),IZW(7),PW(7),IEX
IF (ZPROJ+4.0-BL) 1,1,5
1 KSX=1
2 ZP=CHAML+2.54*(ZPROJ+4.0+XC(7))
CALL IGFZ (ZP,IPRJ)
3 NM=IPRJ
NRK=5+7*IPRJ
IF ((IPRJ-19)18,6,2
CONTINUE
4 DDC=ZP-Z3(IPRJ-2)
VR=(ZP-ZB(IPRJ-1))/GCD
VRC=V(IP0)/(DDO+A3(IPC))
DC 3 K=1,5
F(IPRU,K)=VR*NF(IP0,K)
5 F(IP0,K)=V90*F(IP0,K)
UG(IP0)=UC(IP0-1)+(VPROJ*30,40-U5(IP0-1))*(ZB(IP0)-ZB(IP0-1))/2
(ZP-ZB(IP0-1))
6 UF(IP0)=UP(IP0-1)*(VPROJ*30,40-U5(IP0-1))*(ZB(IP0)-ZB(IP0-1))/2
(ZP-Z5(IP0-1))
7 F(IP0,7)=UP(IP0)*F(IP0,5)
F(IP0,6)=F(IP0,7)+UG(IP0)*F(IP0,1)
L=5
DO 4 I=1,1,MN
DO 4 K=1,7
L=L+1
4 Y(L)=F(I,K)

```

CNTR0400  
CNTR0410  
CNTR0420  
CNTR0430  
CNTR0440  
CNTR0450  
CNTR0460  
CNTR0470  
CNTR0480  
CNTR0490  
CNTR0500  
CNTR0510  
CNTR0520  
CNTR0530  
CNTR0540  
CNTR0550  
CNTR0560  
CNTR0570

- 17 C0TINYE (Y,DX,T)
- 18 C0ALD DEERIV (Y,DX,T)
- 19 IMA01PR3
- 20 C0T06
- 21 IMA01PR4
- 22 C0T09
- 23 C0T11UE
- 24 C0T11UE
- 25 IMA01PR5
- 26 IMA01PR6
- 27 F (P0,5)\*F (P0,7)\*U6 (P0)\*C6 (10);  
F (P0,7)\*U6 (P0)\*F (P0,5)
- 28 IMA01PR7
- 29 IMA01PR8
- 30 IMA01PR9
- 31 IMA01PR10
- 32 IMA01PR11
- 33 C0T11UE
- 34 C0T11UE
- 35 IMA01PR12
- 36 IMA01PR13
- 37 F (P0,5)\*F (P0,7)\*U6 (P0)\*C6 (10);  
F (P0,7)\*U6 (P0)\*F (P0,5)
- 38 IMA01PR14
- 39 IMA01PR15
- 40 IMA01PR16
- 41 IMA01PR17
- 42 IMA01PR18
- 43 IMA01PR19
- 44 IMA01PR20
- 45 IMA01PR21
- 46 IMA01PR22
- 47 IMA01PR23
- 48 IMA01PR24
- 49 IMA01PR25
- 50 IMA01PR26
- 51 IMA01PR27
- 52 IMA01PR28
- 53 IMA01PR29
- 54 IMA01PR30
- 55 IMA01PR31
- 56 IMA01PR32
- 57 IMA01PR33
- 58 IMA01PR34
- 59 IMA01PR35
- 60 IMA01PR36
- 61 IMA01PR37
- 62 IMA01PR38
- 63 IMA01PR39
- 64 IMA01PR40
- 65 IMA01PR41
- 66 IMA01PR42
- 67 IMA01PR43
- 68 IMA01PR44
- 69 IMA01PR45
- 70 IMA01PR46
- 71 IMA01PR47
- 72 IMA01PR48
- 73 IMA01PR49
- 74 IMA01PR50
- 75 IMA01PR51
- 76 IMA01PR52
- 77 IMA01PR53
- 78 IMA01PR54
- 79 IMA01PR55
- 80 IMA01PR56
- 81 IMA01PR57
- 82 IMA01PR58
- 83 IMA01PR59
- 84 IMA01PR60
- 85 IMA01PR61
- 86 IMA01PR62
- 87 IMA01PR63
- 88 IMA01PR64
- 89 IMA01PR65
- 90 IMA01PR66
- 91 IMA01PR67
- 92 IMA01PR68
- 93 IMA01PR69
- 94 IMA01PR70
- 95 IMA01PR71
- 96 IMA01PR72
- 97 IMA01PR73
- 98 IMA01PR74
- 99 IMA01PR75
- 100 IMA01PR76
- 101 IMA01PR77
- 102 IMA01PR78
- 103 IMA01PR79
- 104 IMA01PR80
- 105 IMA01PR81
- 106 IMA01PR82
- 107 IMA01PR83
- 108 IMA01PR84
- 109 IMA01PR85
- 110 IMA01PR86
- 111 IMA01PR87
- 112 IMA01PR88
- 113 IMA01PR89
- 114 IMA01PR90
- 115 IMA01PR91
- 116 IMA01PR92
- 117 IMA01PR93
- 118 IMA01PR94
- 119 IMA01PR95
- 120 IMA01PR96
- 121 IMA01PR97
- 122 IMA01PR98
- 123 IMA01PR99
- 124 IMA01PR100
- 125 IMA01PR101
- 126 IMA01PR102
- 127 IMA01PR103
- 128 IMA01PR104
- 129 IMA01PR105
- 130 IMA01PR106
- 131 IMA01PR107
- 132 IMA01PR108
- 133 IMA01PR109
- 134 IMA01PR110
- 135 IMA01PR111
- 136 IMA01PR112
- 137 IMA01PR113
- 138 IMA01PR114
- 139 IMA01PR115
- 140 IMA01PR116
- 141 IMA01PR117
- 142 IMA01PR118
- 143 IMA01PR119
- 144 IMA01PR120
- 145 IMA01PR121
- 146 IMA01PR122
- 147 IMA01PR123
- 148 IMA01PR124
- 149 IMA01PR125
- 150 IMA01PR126
- 151 IMA01PR127
- 152 IMA01PR128
- 153 IMA01PR129
- 154 IMA01PR130
- 155 IMA01PR131
- 156 IMA01PR132
- 157 IMA01PR133
- 158 IMA01PR134
- 159 IMA01PR135
- 160 IMA01PR136
- 161 IMA01PR137
- 162 IMA01PR138
- 163 IMA01PR139
- 164 IMA01PR140
- 165 IMA01PR141
- 166 IMA01PR142
- 167 IMA01PR143
- 168 IMA01PR144
- 169 IMA01PR145
- 170 IMA01PR146
- 171 IMA01PR147
- 172 IMA01PR148
- 173 IMA01PR149
- 174 IMA01PR150
- 175 IMA01PR151
- 176 IMA01PR152
- 177 IMA01PR153
- 178 IMA01PR154
- 179 IMA01PR155
- 180 IMA01PR156
- 181 IMA01PR157
- 182 IMA01PR158
- 183 IMA01PR159
- 184 IMA01PR160
- 185 IMA01PR161
- 186 IMA01PR162
- 187 IMA01PR163
- 188 IMA01PR164
- 189 IMA01PR165
- 190 IMA01PR166
- 191 IMA01PR167
- 192 IMA01PR168
- 193 IMA01PR169
- 194 IMA01PR170
- 195 IMA01PR171
- 196 IMA01PR172
- 197 IMA01PR173
- 198 IMA01PR174
- 199 IMA01PR175
- 200 IMA01PR176
- 201 IMA01PR177
- 202 IMA01PR178
- 203 IMA01PR179
- 204 IMA01PR180
- 205 IMA01PR181
- 206 IMA01PR182
- 207 IMA01PR183
- 208 IMA01PR184
- 209 IMA01PR185
- 210 IMA01PR186
- 211 IMA01PR187
- 212 IMA01PR188
- 213 IMA01PR189
- 214 IMA01PR190
- 215 IMA01PR191
- 216 IMA01PR192
- 217 IMA01PR193
- 218 IMA01PR194
- 219 IMA01PR195
- 220 IMA01PR196
- 221 IMA01PR197
- 222 IMA01PR198
- 223 IMA01PR199
- 224 IMA01PR200
- 225 IMA01PR201
- 226 IMA01PR202
- 227 IMA01PR203
- 228 IMA01PR204
- 229 IMA01PR205
- 230 IMA01PR206
- 231 IMA01PR207
- 232 IMA01PR208
- 233 IMA01PR209
- 234 IMA01PR210
- 235 IMA01PR211
- 236 IMA01PR212
- 237 IMA01PR213
- 238 IMA01PR214
- 239 IMA01PR215
- 240 IMA01PR216
- 241 IMA01PR217
- 242 IMA01PR218
- 243 IMA01PR219
- 244 IMA01PR220
- 245 IMA01PR221
- 246 IMA01PR222
- 247 IMA01PR223
- 248 IMA01PR224
- 249 IMA01PR225
- 250 IMA01PR226
- 251 IMA01PR227
- 252 IMA01PR228
- 253 IMA01PR229
- 254 IMA01PR230
- 255 IMA01PR231
- 256 IMA01PR232
- 257 IMA01PR233
- 258 IMA01PR234
- 259 IMA01PR235
- 260 IMA01PR236
- 261 IMA01PR237
- 262 IMA01PR238
- 263 IMA01PR239
- 264 IMA01PR240
- 265 IMA01PR241
- 266 IMA01PR242
- 267 IMA01PR243
- 268 IMA01PR244
- 269 IMA01PR245
- 270 IMA01PR246
- 271 IMA01PR247
- 272 IMA01PR248
- 273 IMA01PR249
- 274 IMA01PR250
- 275 IMA01PR251
- 276 IMA01PR252
- 277 IMA01PR253
- 278 IMA01PR254
- 279 IMA01PR255
- 280 IMA01PR256
- 281 IMA01PR257
- 282 IMA01PR258
- 283 IMA01PR259
- 284 IMA01PR260
- 285 IMA01PR261
- 286 IMA01PR262
- 287 IMA01PR263
- 288 IMA01PR264
- 289 IMA01PR265
- 290 IMA01PR266
- 291 IMA01PR267
- 292 IMA01PR268
- 293 IMA01PR269
- 294 IMA01PR270
- 295 IMA01PR271
- 296 IMA01PR272
- 297 IMA01PR273
- 298 IMA01PR274
- 299 IMA01PR275
- 300 IMA01PR276
- 301 IMA01PR277
- 302 IMA01PR278
- 303 IMA01PR279
- 304 IMA01PR280
- 305 IMA01PR281
- 306 IMA01PR282
- 307 IMA01PR283
- 308 IMA01PR284
- 309 IMA01PR285
- 310 IMA01PR286
- 311 IMA01PR287
- 312 IMA01PR288
- 313 IMA01PR289
- 314 IMA01PR290
- 315 IMA01PR291
- 316 IMA01PR292
- 317 IMA01PR293
- 318 IMA01PR294
- 319 IMA01PR295
- 320 IMA01PR296
- 321 IMA01PR297
- 322 IMA01PR298
- 323 IMA01PR299
- 324 IMA01PR300
- 325 IMA01PR301
- 326 IMA01PR302
- 327 IMA01PR303
- 328 IMA01PR304
- 329 IMA01PR305
- 330 IMA01PR306
- 331 IMA01PR307
- 332 IMA01PR308
- 333 IMA01PR309
- 334 IMA01PR310
- 335 IMA01PR311
- 336 IMA01PR312
- 337 IMA01PR313
- 338 IMA01PR314
- 339 IMA01PR315
- 340 IMA01PR316
- 341 IMA01PR317
- 342 IMA01PR318
- 343 IMA01PR319
- 344 IMA01PR320
- 345 IMA01PR321
- 346 IMA01PR322
- 347 IMA01PR323
- 348 IMA01PR324
- 349 IMA01PR325
- 350 IMA01PR326
- 351 IMA01PR327
- 352 IMA01PR328
- 353 IMA01PR329
- 354 IMA01PR330
- 355 IMA01PR331
- 356 IMA01PR332
- 357 IMA01PR333
- 358 IMA01PR334
- 359 IMA01PR335
- 360 IMA01PR336
- 361 IMA01PR337
- 362 IMA01PR338
- 363 IMA01PR339
- 364 IMA01PR340
- 365 IMA01PR341
- 366 IMA01PR342
- 367 IMA01PR343
- 368 IMA01PR344
- 369 IMA01PR345
- 370 IMA01PR346
- 371 IMA01PR347
- 372 IMA01PR348
- 373 IMA01PR349
- 374 IMA01PR350
- 375 IMA01PR351
- 376 IMA01PR352
- 377 IMA01PR353
- 378 IMA01PR354
- 379 IMA01PR355
- 380 IMA01PR356
- 381 IMA01PR357
- 382 IMA01PR358
- 383 IMA01PR359
- 384 IMA01PR360
- 385 IMA01PR361
- 386 IMA01PR362
- 387 IMA01PR363
- 388 IMA01PR364
- 389 IMA01PR365
- 390 IMA01PR366
- 391 IMA01PR367
- 392 IMA01PR368
- 393 IMA01PR369
- 394 IMA01PR370
- 395 IMA01PR371
- 396 IMA01PR372
- 397 IMA01PR373
- 398 IMA01PR374
- 399 IMA01PR375
- 400 IMA01PR376
- 401 IMA01PR377
- 402 IMA01PR378
- 403 IMA01PR379
- 404 IMA01PR380
- 405 IMA01PR381
- 406 IMA01PR382
- 407 IMA01PR383
- 408 IMA01PR384
- 409 IMA01PR385
- 410 IMA01PR386
- 411 IMA01PR387
- 412 IMA01PR388
- 413 IMA01PR389
- 414 IMA01PR390
- 415 IMA01PR391
- 416 IMA01PR392
- 417 IMA01PR393
- 418 IMA01PR394
- 419 IMA01PR395
- 420 IMA01PR396
- 421 IMA01PR397
- 422 IMA01PR398
- 423 IMA01PR399
- 424 IMA01PR400
- 425 IMA01PR401
- 426 IMA01PR402
- 427 IMA01PR403
- 428 IMA01PR404
- 429 IMA01PR405
- 430 IMA01PR406
- 431 IMA01PR407
- 432 IMA01PR408
- 433 IMA01PR409
- 434 IMA01PR410
- 435 IMA01PR411
- 436 IMA01PR412
- 437 IMA01PR413
- 438 IMA01PR414
- 439 IMA01PR415
- 440 IMA01PR416
- 441 IMA01PR417
- 442 IMA01PR418
- 443 IMA01PR419
- 444 IMA01PR420
- 445 IMA01PR421
- 446 IMA01PR422
- 447 IMA01PR423
- 448 IMA01PR424
- 449 IMA01PR425
- 450 IMA01PR426
- 451 IMA01PR427
- 452 IMA01PR428
- 453 IMA01PR429
- 454 IMA01PR430
- 455 IMA01PR431
- 456 IMA01PR432
- 457 IMA01PR433
- 458 IMA01PR434
- 459 IMA01PR435
- 460 IMA01PR436
- 461 IMA01PR437
- 462 IMA01PR438
- 463 IMA01PR439
- 464 IMA01PR440
- 465 IMA01PR441
- 466 IMA01PR442
- 467 IMA01PR443
- 468 IMA01PR444
- 469 IMA01PR445
- 470 IMA01PR446
- 471 IMA01PR447
- 472 IMA01PR448
- 473 IMA01PR449
- 474 IMA01PR450
- 475 IMA01PR451
- 476 IMA01PR452
- 477 IMA01PR453
- 478 IMA01PR454
- 479 IMA01PR455
- 480 IMA01PR456
- 481 IMA01PR457
- 482 IMA01PR458
- 483 IMA01PR459
- 484 IMA01PR460
- 485 IMA01PR461
- 486 IMA01PR462
- 487 IMA01PR463
- 488 IMA01PR464
- 489 IMA01PR465
- 490 IMA01PR466
- 491 IMA01PR467
- 492 IMA01PR468
- 493 IMA01PR469
- 494 IMA01PR470
- 495 IMA01PR471
- 496 IMA01PR472
- 497 IMA01PR473
- 498 IMA01PR474
- 499 IMA01PR475
- 500 IMA01PR476
- 501 IMA01PR477
- 502 IMA01PR478
- 503 IMA01PR479
- 504 IMA01PR480
- 505 IMA01PR481
- 506 IMA01PR482
- 507 IMA01PR483
- 508 IMA01PR484
- 509 IMA01PR485
- 510 IMA01PR486
- 511 IMA01PR487
- 512 IMA01PR488
- 513 IMA01PR489
- 514 IMA01PR490
- 515 IMA01PR491
- 516 IMA01PR492
- 517 IMA01PR493
- 518 IMA01PR494
- 519 IMA01PR495
- 520 IMA01PR496
- 521 IMA01PR497
- 522 IMA01PR498
- 523 IMA01PR499
- 524 IMA01PR500
- 525 IMA01PR501
- 526 IMA01PR502
- 527 IMA01PR503
- 528 IMA01PR504
- 529 IMA01PR505
- 530 IMA01PR506
- 531 IMA01PR507
- 532 IMA01PR508
- 533 IMA01PR509
- 534 IMA01PR510
- 535 IMA01PR511
- 536 IMA01PR512
- 537 IMA01PR513
- 538 IMA01PR514
- 539 IMA01PR515
- 540 IMA01PR516
- 541 IMA01PR517
- 542 IMA01PR518
- 543 IMA01PR519
- 544 IMA01PR520
- 545 IMA01PR521
- 546 IMA01PR522
- 547 IMA01PR523
- 548 IMA01PR524
- 549 IMA01PR525
- 550 IMA01PR526
- 551 IMA01PR527
- 552 IMA01PR528
- 553 IMA01PR529
- 554 IMA01PR530
- 555 IMA01PR531
- 556 IMA01PR532
- 557 IMA01PR533
- 558 IMA01PR534
- 559 IMA01PR535
- 560 IMA01PR536
- 561 IMA01PR537
- 562 IMA01PR538
- 563 IMA01PR539
- 564 IMA01PR540
- 565 IMA01PR541
- 566 IMA01PR542
- 567 IMA01PR543
- 568 IMA01PR544
- 569 IMA01PR545
- 570 IMA01PR546
- 571 IMA01PR547
- 572 IMA01PR548
- 573 IMA01PR549
- 574 IMA01PR550
- 575 IMA01PR551
- 576 IMA01PR552
- 577 IMA01PR553
- 578 IMA01PR554
- 579 IMA01PR555
- 580 IMA01PR556
- 581 IMA01PR557
- 582 IMA01PR558
- 583 IMA01PR559
- 584 IMA01PR560
- 585 IMA01PR561
- 586 IMA01PR562
- 587 IMA01PR563
- 588 IMA01PR564
- 589 IMA01PR565
- 590 IMA01PR566
- 591 IMA01PR567
- 592 IMA01PR568
- 593 IMA01PR569
- 594 IMA01PR570
- 595 IMA01PR571
- 596 IMA01PR572
- 597 IMA01PR573
- 598 IMA01PR574
- 599 IMA01PR575
- 600 IMA01PR576
- 601 IMA01PR577
- 602 IMA01PR578
- 603 IMA01PR579
- 604 IMA01PR580
- 605 IMA01PR581
- 606 IMA01PR582
- 607 IMA01PR583
- 608 IMA01PR584
- 609 IMA01PR585
- 610 IMA01PR586
- 611 IMA01PR587
- 612 IMA01PR588
- 613 IMA01PR589
- 614 IMA01PR590
- 615 IMA01PR591
- 616 IMA01PR592
- 617 IMA01PR593
- 618 IMA01PR594
- 619 IMA01PR595
- 620 IMA01PR596
- 621 IMA01PR597
- 622 IMA01PR598
- 623 IMA01PR599
- 624 IMA01PR600
- 625 IMA01PR601
- 626 IMA01PR602
- 627 IMA01PR603
- 628 IMA01PR604
- 629 IMA01PR605
- 630 IMA01PR606
- 631 IMA01PR607
- 632 IMA01PR608
- 633 IMA01PR609
- 634 IMA01PR610
- 635 IMA01PR611
- 636 IMA01PR612
- 637 IMA01PR613
- 638 IMA01PR614
- 639 IMA01PR615
- 640 IMA01PR616
- 641 IMA01PR617
- 642 IMA01PR618
- 643 IMA01PR619
- 644 IMA01PR620
- 645 IMA01PR621
- 646 IMA01PR622
- 647 IMA01PR623
- 648 IMA01PR624
- 649 IMA01PR625
- 650 IMA01PR626
- 651 IMA01PR627
- 652 IMA01PR628
- 653 IMA01PR629
- 654 IMA01PR630
- 655 IMA01PR631
- 656 IMA01PR632
- 657 IMA01PR633
- 658 IMA01PR634
- 659 IMA01PR635
- 660 IMA01PR636
- 661 IMA01PR637
- 662 IMA01PR638
- 663 IMA01PR639
- 664 IMA01PR640
- 665 IMA01PR641
- 666 IMA01PR642
- 667 IMA01PR643
- 668 IMA01PR644
- 669 IMA01PR645
- 670 IMA01PR646
- 671 IMA01PR647
- 672 IMA01PR648
- 673 IMA01PR649
- 674 IMA01PR650
- 675 IMA01PR651
- 676 IMA01PR652
- 677 IMA01PR653
- 678 IMA01PR654
- 679 IMA01PR655
- 680 IMA01PR656
- 681 IMA01PR657
- 682 IMA01PR658
- 683 IMA01PR659
- 684 IMA01PR660
- 685 IMA01PR661
- 686 IMA01PR662
- 687 IMA01PR663
- 688 IMA01PR664
- 689 IMA01PR665
- 690 IMA01PR666
- 691 IMA01PR667
- 692 IMA01PR668
- 693 IMA01PR669
- 694 IMA01PR670
- 695 IMA01PR671
- 696 IMA01PR672
- 697 IMA01PR673
- 698 IMA01PR674
- 699 IMA01PR675
- 700 IMA01PR676
- 701 IMA01PR677
- 702 IMA01PR678
- 703 IMA01PR679
- 704 IMA01PR680
- 705 IMA01PR681
- 706 IMA01PR682
- 707 IMA01PR683
- 708 IMA01PR684
- 709 IMA01PR685
- 710 IMA01PR686
- 711 IMA01PR687
- 712 IMA01PR688
- 713 IMA01PR689
- 714 IMA01PR690
- 715 IMA01PR691
- 716 IMA01PR692
- 717 IMA01PR693
- 718 IMA01PR694
- 719

## ONE DIMENSIONAL GAS PARTICLE FLOW

```

144 FORMAT(1H0,7X,1H!,4X,2HEC,12X,3HCA,11X,2HTP,12X,2HFN,12X,2HDP,
145   2H12X,2HOC,12X,3HSCA,11X,3HGE4 / 1H,18,1PE14,6,7E14,6)
146 WRITE(6,105) (1,FM(1),FMV(1),I=1,IMNP1)
147 FCNWT(1H0,7X,1H!,4X,2HFM,12X,3+FMV / 1H,18,1PE14,6,E14,6)
148 IPL3=MINT1,N,1PL2)
149 CALL PLOTS(2,PG,30,PG,1,IPL1,IP-3,2J0,1H*,1H*,1HG,1H*,0,0,0,0,
150   20,0)
151 CALL PLOTS(2,FN,SV,PG,1,IPL1,IP-3,200,1HN,1H*,1H*,0,0,0,0,0,
152   20,0)
153 CALL PLOTS(2,G,UP,PG,25,2,1PL1,IP-3,200,1HG,1H*,0,0,0,0,0,0,
154   20,0)
155 WRITE(6,126)
156 FORMAT(1H1-1;X,1)
157 CONTINUE
158 END

```

#### ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE DRAGC(FE,CORE,FMACH)
DATA N / 1 /
CC7C(1,2),1
RE23=(16.5/C,4)*0.5
N2
CC7C7
IF (FE-2E12) 3,4,4
3 CC7C=24.5
4 CORE=0.44*FE
5 CORE=18.5*RCOT(RCOT(FE,5))
6 CONTINUE
7 IF (FMACH<0.41) 8,9,9
8 CORE=0
9 RETURN
END

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```
SUBROUTINE EGSTAT (E,RHO,P)
F1 = 1.6663384E 05+RHO*( 2.3860914E 05+RHO* 1.8121513E 05)
F2 = 8.804000 E 01+RHO*( 2.039948 E 02+RHO*-1.7081190E 01)
F3 =-3.9915C83E -02+RHO*(-6.3478293E -03+RHO*-1.0366801E -01)
P=RHO*(F1+E*(F2+E*F3))
RETURN
END
```

ONE DIMENSIONAL GAS PARTICLE FLOW

```
SUBROUTINE TOEAR (E,RHO,T)
F1 =3.6C7725E 3+RHO*(1.041906E 3-2RH0*1.501111E 3)
F2 =1.655822+R.H0*(2.115313-2RH0*1.548174)
F3 =-C :07984E -2+RHO*(-0.686307E -3+RHO*0.422347E -2)
T=F1+E*(F2+E*F3)
RETURN
END
```

ONE DIMENSIONAL GAS PARTICLE FLOW

```
SUBROUTINE LOFU (U,L)
IF (U) 2,1,1
1 LSC
2 RETURN
2 L21
3 RETURN
END
```

## ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE RK2 (DERIV,CNTRL,Y,DY,A,R,T,DT,N,DTM)
C
C   SECOND ORDER RUNGE KUTTA
C   NTRY IS ASSIGNED ONE OF THE VALUES LISTED BELOW IN CNTRL
C
C   NTRY = 1  CONTINUE INTEGRATION
C   NTRY = 2  RETURN FROM RUNGE KUTTA
C   NTRY = 3  REPEAT STEP WITH NEW DT GIVEN IN CNTRL
C   NTRY = 4  CONTINUE INTEGRATION WITH FIXED STEP
C
PARAMETER NRK=1800
CIVEVISION Y(NRKD),DY(NRKD),A(NRKD),R(NRKD),YST(NRKD),
C        C/NRK / NRK/ NRK
EXTERNAL DERIV,CNTRL
TWA10=10,*(1.0/3.0)
GA=3.5
BETA=0.5/GAM
ALPHA=1.0-BETA
CALL DERIV (Y,DY,T)
CALL CNTRL(Y,DY,DT,T,NTHY)
TST=T
4   N=NRK
DO 5  I=1,N
      YST(I)=Y(I)
      5  DYST(I)=DY(I)
      6  IF (DT) 8,7,8
      7  WRITE (6,121)
      121 FORMAT (1H0,20X,17HSTEP SIZE = ZERO, )
      RETURN
      8  T=TST+GAM*DT
      9  QC 9  I=1,N
      9  Y(I)=YST(I)+GAM*DT*DYST(I)
      CALL DERIV (Y,DY,T)
      T=TST+DT
      DO 10 I=1,N
      15  Y(I)=YST(I)+DT*(ALPHA*DYST(I)+BETA*DY(I))
      15  CALL DERIV (Y,DY,T)
      EOCH=J,0
      DC 13  I=1,N
      E=Y(I)-(YST(I)+0.5*DT*(DYST(I)+DY(I)))
      C=I+R(I)*A3S(Y(I))
      IF (C) 12,11,12
      12
      11
      8
      7
      6
      5
      4
      3
      2
      1
      0
      9
      10
      11
      12
      13
      14
      15
      16
      17
      18
      19
      20
      21
      22
      23
      24
      25
      26
      27
      28
      29
      30
      31
      32
      33
      34
      35
      36
      37
      38
      39
      40
      41
      42
      43
      44
      45
      46
      47
      48
      49
      50
      51
      52
      53
      54
      55
      56
      57
      58
      59
      60
      61
      62
      63
      64
      65
      66
      67
      68
      69
      70
      71
      72
      73
      74
      75
      76
      77
      78
      79
      80
      81
      82
      83
      84
      85
      86
      87
      88
      89
      90
      91
      92
      93
      94
      95
      96
      97
      98
      99
      100
      101
      102
      103
      104
      105
      106
      107
      108
      109
      110
      111
      112
      113
      114
      115
      116
      117
      118
      119
      120
      121
      122
      123
      124
      125
      126
      127
      128
      129
      130
      131
      132
      133
      134
      135
      136
      137
      138
      139
      140
      141
      142
      143
      144
      145
      146
      147
      148
      149
      150
      151
      152
      153
      154
      155
      156
      157
      158
      159
      160
      161
      162
      163
      164
      165
      166
      167
      168
      169
      170
      171
      172
      173
      174
      175
      176
      177
      178
      179
      180
      181
      182
      183
      184
      185
      186
      187
      188
      189
      190
      191
      192
      193
      194
      195
      196
      197
      198
      199
      200
      201
      202
      203
      204
      205
      206
      207
      208
      209
      210
      211
      212
      213
      214
      215
      216
      217
      218
      219
      220
      221
      222
      223
      224
      225
      226
      227
      228
      229
      230
      231
      232
      233
      234
      235
      236
      237
      238
      239
      240
      241
      242
      243
      244
      245
      246
      247
      248
      249
      250
      251
      252
      253
      254
      255
      256
      257
      258
      259
      260
      261
      262
      263
      264
      265
      266
      267
      268
      269
      270
      271
      272
      273
      274
      275
      276
      277
      278
      279
      280
      281
      282
      283
      284
      285
      286
      287
      288
      289
      290
      291
      292
      293
      294
      295
      296
      297
      298
      299
      300
      301
      302
      303
      304
      305
      306
      307
      308
      309
      310
      311
      312
      313
      314
      315
      316
      317
      318
      319
      320
      321
      322
      323
      324
      325
      326
      327
      328
      329
      330
      331
      332
      333
      334
      335
      336
      337
      338
      339
      340
      341
      342
      343
      344
      345
      346
      347
      348
      349
      350
      351
      352
      353
      354
      355
      356
      357
      358
      359
      360
      361
      362
      363
      364
      365
      366
      367
      368
      369
      370
      371
      372
      373
      374
      375
      376
      377
      378
      379
      380
      381
      382
      383
      384
      385
      386
      387
      388
      389
      390
      391
      392
      393
      394
      395
      396
      397
      398
      399
      400
      401
      402
      403
      404
      405
      406
      407
      408
      409
      410
      411
      412
      413
      414
      415
      416
      417
      418
      419
      420
      421
      422
      423
      424
      425
      426
      427
      428
      429
      430
      431
      432
      433
      434
      435
      436
      437
      438
      439
      440
      441
      442
      443
      444
      445
      446
      447
      448
      449
      450
      451
      452
      453
      454
      455
      456
      457
      458
      459
      460
      461
      462
      463
      464
      465
      466
      467
      468
      469
      470
      471
      472
      473
      474
      475
      476
      477
      478
      479
      480
      481
      482
      483
      484
      485
      486
      487
      488
      489
      490
      491
      492
      493
      494
      495
      496
      497
      498
      499
      500
      501
      502
      503
      504
      505
      506
      507
      508
      509
      510
      511
      512
      513
      514
      515
      516
      517
      518
      519
      520
      521
      522
      523
      524
      525
      526
      527
      528
      529
      530
      531
      532
      533
      534
      535
      536
      537
      538
      539
      540
      541
      542
      543
      544
      545
      546
      547
      548
      549
      550
      551
      552
      553
      554
      555
      556
      557
      558
      559
      560
      561
      562
      563
      564
      565
      566
      567
      568
      569
      570
      571
      572
      573
      574
      575
      576
      577
      578
      579
      580
      581
      582
      583
      584
      585
      586
      587
      588
      589
      590
      591
      592
      593
      594
      595
      596
      597
      598
      599
      600
      601
      602
      603
      604
      605
      606
      607
      608
      609
      610
      611
      612
      613
      614
      615
      616
      617
      618
      619
      620
      621
      622
      623
      624
      625
      626
      627
      628
      629
      630
      631
      632
      633
      634
      635
      636
      637
      638
      639
      640
      641
      642
      643
      644
      645
      646
      647
      648
      649
      650
      651
      652
      653
      654
      655
      656
      657
      658
      659
      660
      661
      662
      663
      664
      665
      666
      667
      668
      669
      670
      671
      672
      673
      674
      675
      676
      677
      678
      679
      680
      681
      682
      683
      684
      685
      686
      687
      688
      689
      690
      691
      692
      693
      694
      695
      696
      697
      698
      699
      700
      701
      702
      703
      704
      705
      706
      707
      708
      709
      710
      711
      712
      713
      714
      715
      716
      717
      718
      719
      720
      721
      722
      723
      724
      725
      726
      727
      728
      729
      730
      731
      732
      733
      734
      735
      736
      737
      738
      739
      740
      741
      742
      743
      744
      745
      746
      747
      748
      749
      750
      751
      752
      753
      754
      755
      756
      757
      758
      759
      760
      761
      762
      763
      764
      765
      766
      767
      768
      769
      770
      771
      772
      773
      774
      775
      776
      777
      778
      779
      779
      780
      781
      782
      783
      784
      785
      786
      787
      788
      789
      790
      791
      792
      793
      794
      795
      796
      797
      798
      799
      800
      801
      802
      803
      804
      805
      806
      807
      808
      809
      809
      810
      811
      812
      813
      814
      815
      816
      817
      818
      819
      819
      820
      821
      822
      823
      824
      825
      826
      827
      828
      829
      829
      830
      831
      832
      833
      834
      835
      836
      837
      838
      839
      839
      840
      841
      842
      843
      844
      845
      846
      847
      848
      849
      849
      850
      851
      852
      853
      854
      855
      856
      857
      858
      859
      859
      860
      861
      862
      863
      864
      865
      866
      867
      868
      869
      869
      870
      871
      872
      873
      874
      875
      876
      877
      878
      879
      879
      880
      881
      882
      883
      884
      885
      886
      887
      888
      889
      889
      890
      891
      892
      893
      894
      895
      896
      897
      898
      899
      900
      901
      902
      903
      904
      905
      906
      907
      908
      909
      909
      910
      911
      912
      913
      914
      915
      916
      917
      918
      919
      919
      920
      921
      922
      923
      924
      925
      926
      927
      928
      929
      929
      930
      931
      932
      933
      934
      935
      936
      937
      938
      939
      939
      940
      941
      942
      943
      944
      945
      946
      947
      948
      949
      949
      950
      951
      952
      953
      954
      955
      956
      957
      958
      959
      959
      960
      961
      962
      963
      964
      965
      966
      967
      968
      969
      969
      970
      971
      972
      973
      974
      975
      976
      977
      978
      979
      979
      980
      981
      982
      983
      984
      985
      986
      987
      988
      989
      989
      990
      991
      992
      993
      994
      995
      996
      997
      998
      999
      999
      1000
      1001
      1002
      1003
      1004
      1005
      1006
      1007
      1008
      1009
      1009
      1010
      1011
      1012
      1013
      1014
      1015
      1016
      1017
      1018
      1019
      1019
      1020
      1021
      1022
      1023
      1024
      1025
      1026
      1027
      1028
      1029
      1029
      1030
      1031
      1032
      1033
      1034
      1035
      1036
      1037
      1038
      1039
      1039
      1040
      1041
      1042
      1043
      1044
      1045
      1046
      1047
      1048
      1049
      1049
      1050
      1051
      1052
      1053
      1054
      1055
      1056
      1057
      1058
      1059
      1059
      1060
      1061
      1062
      1063
      1064
      1065
      1066
      1067
      1068
      1069
      1069
      1070
      1071
      1072
      1073
      1074
      1075
      1076
      1077
      1078
      1078
      1079
      1080
      1081
      1082
      1083
      1084
      1085
      1086
      1087
      1088
      1088
      1089
      1090
      1091
      1092
      1093
      1094
      1095
      1096
      1096
      1097
      1098
      1099
      1099
      1100
      1101
      1102
      1103
      1104
      1105
      1106
      1107
      1108
      1109
      1109
      1110
      1111
      1112
      1113
      1114
      1115
      1116
      1117
      1118
      1119
      1119
      1120
      1121
      1122
      1123
      1124
      1125
      1126
      1127
      1128
      1129
      1129
      1130
      1131
      1132
      1133
      1134
      1135
      1136
      1137
      1138
      1139
      1139
      1140
      1141
      1142
      1143
      1144
      1145
      1146
      1147
      1148
      1149
      1149
      1150
      1151
      1152
      1153
      1154
      1155
      1156
      1157
      1158
      1159
      1159
      1160
      1161
      1162
      1163
      1164
      1165
      1166
      1167
      1168
      1169
      1169
      1170
      1171
      1172
      1173
      1174
      1175
      1176
      1177
      1178
      1178
      1179
      1180
      1181
      1182
      1183
      1184
      1185
      1186
      1187
      1188
      1188
      1189
      1190
      1191
      1192
      1193
      1194
      1195
      1196
      1196
      1197
      1198
      1199
      1199
      1200
      1201
      1202
      1203
      1204
      1205
      1206
      1207
      1208
      1209
      1209
      1210
      1211
      1212
      1213
      1214
      1215
      1216
      1217
      1218
      1219
      1219
      1220
      1221
      1222
      1223
      1224
      1225
      1226
      1227
      1228
      1229
      1229
      1230
      1231
      1232
      1233
      1234
      1235
      1236
      1237
      1238
      1239
      1239
      1240
      1241
      1242
      1243
      1244
      1245
      1246
      1247
      1248
      1249
      1249
      1250
      1251
      1252
      1253
      1254
      1255
      1256
      1257
      1258
      1259
      1259
      1260
      1261
      1262
      1263
      1264
      1265
      1266
      1267
      1268
      1269
      1269
      1270
      1271
      1272
      1273
      1274
      1275
      1276
      1277
      1278
      1278
      1279
      1280
      1281
      1282
      1283
      1284
      1285
      1286
      1287
      1288
      1288
      1289
      1290
      1291
      1292
      1293
      1294
      1295
      1296
      1296
      1297
      1298
      1299
      1299
      1300
      1301
      1302
      1303
      1304
      1305
      1306
      1307
      1308
      1309
      1309
      1310
      1311
      1312
      1313
      1314
      1315
      1316
      1317
      1318
      1319
      1319
      1320
      1321
      1322
      1323
      1324
      1325
      1326
      1327
      1328
      1329
      1329
      1330
      1331
      1332
      1333
      1334
      1335
      1336
      1337
      1338
      1339
      1339
      1340
      1341
      1342
      1343
      1344
      1345
      1346
      1347
      1348
      1349
      1349
      1350
      1351
      1352
      1353
      1354
      1355
      1356
      1357
      1358
      1359
      1359
      1360
      1361
      1362
      1363
      1364
      1365
      1366
      1367
      1368
      1369
      1369
      1370
      1371
      1372
      1373
      1374
      1375
      1376
      1377
      1378
      1378
      1379
      1380
      1381
      1382
      1383
      1384
      1385
      1386
      1387
      1388
      1388
      1389
      1390
      1391
      1392
      1393
      1394
      1395
      1396
      1397
      1398
      1399
      1399
      1400
      1401
      1402
      1403
      1404
      1405
      1406
      1407
      1408
      1409
      1409
      1410
      1411
      1412
      1413
      1414
      1415
      1416
      1417
      1418
      1419
      1419
      1420
      1421
      1422
      1423
      1424
      1425
      1426
      1427
      1428
      1429
      1429
      1430
      1431
      1432
      1433
      1434
      1435
      1436
      1437
      1438
      1439
      1439
      1440
      1441
      1442
      1443
      1444
      1445
      1446
      1447
      1448
      1449
      1449
      1450
      1451
      1452
      1453
      1454
      1455
      1456
      1457
      1458
      1459
      1459
      1460
      1461
      1462
      1463
      1464
      1465
      1466
      1467
      1468
      1469
      1469
      1470
      1471
      1472
      1473
      1474
      1475
      1476
      1477
      1478
      1478
      1479
      1480
      1481
      1482
      1483
      1484
      1485
      1486
      1487
      1488
      1488
      1489
      1490
      1491
      1492
      1493
      1494
      1495
      1496
      1497
      1498
      1499
      1499
      1500
      1501
      1502
      1503
      1504
      1505
      1506
      1507
      1508
      1509
      1509
      1510
      1511
      1512
      1513
      1514
      1515
      1516
      1517
      1518
      1519
      1519
      1520
      1521
      1522
      1523
      1524
      1525
      1526
      1527
      1528
      1529
      1529
      1530
      1531
      1532
      1533
      1534
      1535
      1536
      1537
      1538
      1539
      1539
      1540
      1541
      1542
      1543
      1544
      1545
      1546
      1547
      1548
      1549
      1549
      1550
      1551
      1552
      1553
      1554
      1555
      1556
      1557
      1558
      1559
      1559
      1560
      1561
      1562
      1563
      156
```

```

11 WRITE (6,132)
12 FORMAT (1H0, 20X, 27HA(1)+R(1)*ABS(Y(1))-0 AT 11 , 16)
13 RETURN
14 EOC=ABS(E/C)
C   ECC4=4*1X1(EOC,ECC4)
15 IF (EOC-ECC4) 13,13,201
201 EOCY=EOC
LS21
16 CONTINUE
17 IS=(LS+1)/7
KS=LS-5-7*(IS-1)
18 IF (ECC4-L,0; 17,17,14
19 CONTINUE
20 WRITE (6,321) EOC,LS,KS,IS
321 FORMAT (1H ,10X,S-EOCM,1PE12.5,5X,34LS,16,5X,34KS,16,5X,
2 3-1S,16)
C   CALL DUMPE
T=TST

```

RK2 0400  
RK2 0410  
RK2 0420  
RK2 0430  
RK2 0440  
RK2 0450  
RK2 0460  
RK2 0470  
RK2 0480  
RK2 0490  
RK2 0500  
RK2 0510  
RK2 0520  
RK2 0530  
RK2 0540  
RK2 0550  
RK2 0560  
RK2 0570

ONE DIMENSIONAL GAS PARTICLE FLOW

```

DO 15 I=1,N
Y(I)=YST(I)
15 DY(I)=YST(I)
ECCM=EOCM/10.0
DT=DT/THR10
IF (EOCM-1.0) 6,6,16
16 CONTINUE
GO TO 6
17 CALL CNTRL(Y,DY,DT,T,NTRY)
GO TO (21,18,19,4),NTRY
18 RETURN
19 T=TST
20 DC 20 I=1,N
Y(I)=YST(I)
21 DY(I)=YST(I)
22 DT=DT/THR10
WRITE (6,301) EOCH,LS,KS,IS
23 GO TO 6
24 IF (EOCM-C,3) 23,23,22
25 DT=DT/THR10
IF(ABS(DT)-ABS(DTM)) 4,4,24
DT=ABS(DTM)*DT/ABS(DT)
26 GO TO 4
END
      RK2 0560
      RK2 0590
      RK2 0600
      RK2 0610
      RK2 0620
      RK2 0630
      RK2 0640
      RK2 0650
      RK2 0660
      RK2 0670
      RK2 0680
      RK2 0690
      RK2 0700
      RK2 0710
      RK2 0720
      RK2 0730
      RK2 0740
      RK2 0750
      RK2 0760
      RK2 0770
      RK2 0780
      RK2 0790
      RK2 0800
      RK2 0810
      RK2 0820
      RK2 0830
      RK2 0840

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE CALX(CNA1, CNA2, RN, DT, DEXC, BL, O, VCHAMB, ENL, XC, XBB)
DIMENSION XC(9)
XC(1)=1.0E+37
XC(2)=3.0
XC(3)=-ENL
XC(4)=3.0
TC(1)=STA\*(3.141593*ANG/180.0)
SC(1)=TCNA1/SCRT(1.0+C+TCNA1*0.02)
CC\NA1=2.0*COS(3.141593*CN1/180.0)
IF (ENL-1.0E-10) 16,16,17
16 ANG=CN1
      GC TO 18
17 ANG=3.0
18 SANG=SIN(3.141593*ANG/180.0)
19 RC=2.0
RCC=R\B*(1.0/1.0)/(SCRT(2.0)-1.0)/SCRT(2.0)-SANG-SCRT(1.0-SANG*0.02)
XC(2)=3.0E-ENL+RCC*(SCRT(1.0-SANG*0.02)-1.0/SCRT(2.0))
RXC2=3.5*DEXC+RCC*(SCRT(1.0-SANG*0.02)-1.0/SCRT(2.0))
01=0.25,4
XC15=3.0*(DEXC-DTH)/TCNA1
XC(6)=XC(5)+12.0
XBB=0.5*(XC(6)+5.0*CI-BTH)/TCNA1
CHL=4.0*VCHAMB/(3.141593*0.02)
XC(8)=XC(7)+CHL+BL
XC(9)=1.0E37
X1=X(21)
X2=X(22)
X3=1.0
X4=0.0
RETURN
ENTRY RADIUS(XCN1,2)
X=XC/2.54
IF (X-X2) 4,3,3
3 IF (X-X2) 7,7,4
4 DO 5 I=1,9
      J=1
      5 CO,TINUE
      6 K=j-1

```

92E 91 HENSIIONAL GAS PARTICLE FLOW

```

CC TO 15      R=2.501+SQRT ((X-XC(8))*(2+A*A))-1
CONTINUE
R=2.054
RETURN
END

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE ZSPACE
PARAMETER NDC=200
DIMENSION ZS(200)
COMMON /ALL/ IM,K,P,KM,IPL2,KST,KKST,IMJ,KS,KK,KKO,
2 NFS,NPS,NPE,IP0,IP1,X3B,ZMAX,ZR,VHL(NDC),VHR(NDC),
3 FL,RHOP,VISCG,VFMIV,PDF,FJ,CM4X,PV1,PV2,PV3,CHARG,PROJW,CHAML,
4 WICTH,CPP,BL,FORCE,OSCPSI,SR,SYCT,AC,CCPCIN,AC,VPROJ,ZPROJ,PB,
5 F(NDC,7),CG(NDC),EC(NDC),EN(NDC),TP(NDC),FM(NDC),UG(NDC),
6 UF(NDC),A(NDC),AB(NDC),V(NDC),V3(NDC),XC(9),RHOG(NDC),
7 PC(NDC),DP(NDC),DG(NDC),GF(NDC,7),G(NDC,7),G(NDC),Z(NDC),
8 TGA(NDC),GC(NDC),GEA(NDC),VFA(NDC),FMV(NDC),
1 M3=1,M+1,ZSPAC110
2 ZSPAC120
3 ZSPAC130
4 ZSPAC140
5 ZSPAC150
6 ZSPAC160
7 ZSPAC170
8 ZSPAC180
9 ZSPAC190
10 ZSPAC200
11 ZSPAC210
12 ZSPAC220
13 ZSPAC230
14 ZSPAC240
15 ZSPAC250
16 ZSPAC260
17 ZSPAC270
18 ZSPAC280
19 ZSPAC290
20 ZSPAC300
21 ZSPAC310
22 ZSPAC320
23 ZSPAC330
24 ZSPAC340
25 ZSPAC350
26 ZSPAC360
27 ZSPAC370
28 ZSPAC380
29 ZSPAC390

      CALL UNECR (1,M3,1,WC,IR,ZRC,ZS)
      ZRC=ZR*2.54
      ZM4XC=ZM4X*2.54
      I=M3
      DO 8 L=1,1000
      J=J-1
      IF (J) 2,1,2
      1 J=-2
      2 JAS=ABS(J)
      2 ZST=2S(J)
      1 IF (J) 4,5,3
      3 ZL=X33*2.54-ZST
      3 GC=TC/5
      4 ZL=X33*2.54-ZST
      5 IF ((L/2)*2-L) 6,7,6
      6 I=I+1
      6 Z(I)=ZL
      GO TO 8
      7 ZB(I)=ZL
      7 IF ((I-1)*2-L) 8,10,13
      8 CONTINUE
      10 CONTINUE
      R2C=0.0
      DO 9 I=1,IM
      9 CALL RADIUS (ZB(I),R2)
      CALL RADIUS (ZB(1),R2)

```

```
ZSPA0400  
ZSPA0410  
ZSPA0420  
ZSPA0430  
ZSPA0440  
ZSPA0450  
ZSPA0460  
ZSPA0470  
ZSPA0480  
ZSPA0490  
ZSPA0500  
ZSPA0510  
ZSPA0520  
ZSPA0530  
ZSPA0540  
  
A(1)=3.141593*R*2  
AB(1)=3.141593*R2*#2  
I41=M4XG(1-1)  
VHR(1)=3.141593*(2*(1)-2*(1)*(32*R2+32*R*R)/3.0  
YHL(1)=3.141593*(2*(1)-2*(1)*(2*R2+R20*R20)/3.0  
K22=R2  
  
* CONTINUE  
VHL(1)=VH(1)  
VHR(1)=VHL(1)  
VHL(1)=VHL(1+1)  
DO 11 I=1,14  
11 V(1)=VHL(1)+VHL(1+1)  
11 V(1)=VHL(1)+VHL(1+1)  
11 RETURN  
END
```

ONE DIMENSIONAL GAS PARTICLE FLOW

SUBROUTINE IOFZ(IZZ,III)

```

PARAMETER NDC=200
COMMON /ALL/ IN,K,XP,KM,IPL1,IPL2,XST,IMW,KSD,KXD,
2 NFS,NPE,NPS,NEP,IPRJ,IP0,XSS,ZMAX,ZI,IR,YHL(NDC),VHL(NDC),
3 FL,ZNCP,VISCG,VF11Y,PDF,FJ,CMAX,PV1,PV2,PV3,CHARG,PROJW,CHAML,
4 WIDTH,CPP,BL,FORCE,DSCP5I,SR,JYDT,A5,CCPCIN,AC,VPROJ,ZPROJ,PB,
5 FNDC,71,CG(NDC),EG(NDC),FN(NDC),TP(NDC),FM(NDC),UG(NDC),
6 UG(NDC),AB(NDC),V(NDC),V3(NDC),XC(9),RHOG(NDC),PG(NDC),
7 P2(NDC),DP(NDC),DG(NDC),DF(NDC),G(NDC),Z(NDC),ZS(NDC)
8 ,TGA(NDC),GC(NDC),GEA(NDC),VFA(NDC),VFMV(NDC)
DATA LLL / 1 /
GO TO (1,2),LLL
1 Z1=Z(1)
2 Z2=Z(2)
10=1
LLL=2
1 IF (ZZ-Z1) 5,3,3
3 IF (ZZ-Z2) 4,6,6
4 I=10
5 RETURN
5 IS=1
6 GO TO 7
6 IS=10
7 DC 8 I=IS,14
8 J=1
1 IF (ZZ-Z1) 10,9,3
9 CD,TINUE
9 II=J
10 GO TO 11
10 II=J-1
11 GO TO 11
11 II=1
12 Z2=Z(I+1)
13 RETURN
END

```

	END RETURN	
22-29(1G+1)		
21-23(10)		
10-11		
11-12		
10-13		
11-14		
12-15		
13-16		
14-17		
15-18		
16-19		
17-20		
18-21		
19-22		
20-23		
21-24		
22-25		
23-26		
24-27		
25-28		
26-29		
27-30		
28-31		
29-32		
30-33		
31-34		
32-35		
33-36		
34-37		
35-38		
36-39		
37-40		
38-41		
39-42		
40-43		
41-44		
42-45		
43-46		
44-47		
45-48		
46-49		
47-50		
48-51		
49-52		
50-53		
51-54		
52-55		
53-56		
54-57		
55-58		
56-59		
57-60		
58-61		
59-62		
60-63		
61-64		
62-65		
63-66		
64-67		
65-68		
66-69		
67-70		
68-71		
69-72		
70-73		
71-74		
72-75		
73-76		
74-77		
75-78		
76-79		
77-80		
78-81		
79-82		
80-83		
81-84		
82-85		
83-86		
84-87		
85-88		
86-89		
87-90		
88-91		
89-92		
90-93		
91-94		
92-95		
93-96		
94-97		
95-98		
96-99		
97-100		
98-101		
99-102		
100-103		
101-104		
102-105		
103-106		
104-107		
105-108		
106-109		
107-110		
108-111		
109-112		
110-113		
111-114		
112-115		
113-116		
114-117		
115-118		
116-119		
117-120		
118-121		
119-122		
120-123		
121-124		
122-125		
123-126		
124-127		
125-128		
126-129		
127-130		
128-131		
129-132		
130-133		
131-134		
132-135		
133-136		
134-137		
135-138		
136-139		
137-140		
138-141		
139-142		
140-143		
141-144		
142-145		
143-146		
144-147		
145-148		
146-149		
147-150		
148-151		
149-152		
150-153		
151-154		
152-155		
153-156		
154-157		
155-158		
156-159		
157-160		
158-161		
159-162		
160-163		
161-164		
162-165		
163-166		
164-167		
165-168		
166-170		
167-171		
168-172		
169-173		
170-174		
171-175		
172-176		
173-177		
174-178		
175-179		
176-180		
177-181		
178-182		
179-183		
180-184		
181-185		
182-186		
183-187		
184-188		
185-189		
186-190		
187-191		
188-192		
189-193		
190-194		
191-195		
192-196		
193-197		
194-198		
195-199		
196-200		
197-201		
198-202		
199-203		
200-204		
201-205		
202-206		
203-207		
204-208		
205-209		
206-210		
207-211		
208-212		
209-213		
210-214		
211-215		
212-216		
213-217		
214-218		
215-219		
216-220		
217-221		
218-222		
219-223		
220-224		
221-225		
222-226		
223-227		
224-228		
225-229		
226-230		
227-231		
228-232		
229-233		
230-234		
231-235		
232-236		
233-237		
234-238		
235-239		
236-240		
237-241		
238-242		
239-243		
240-244		
241-245		
242-246		
243-247		
244-248		
245-249		
246-250		
247-251		
248-252		
249-253		
250-254		
251-255		
252-256		
253-257		
254-258		
255-259		
256-260		
257-261		
258-262		
259-263		
260-264		
261-265		
262-266		
263-267		
264-268		
265-269		
266-270		
267-271		
268-272		
269-273		
270-274		
271-275		
272-276		
273-277		
274-278		
275-279		
276-280		
277-281		
278-282		
279-283		
280-284		
281-285		
282-286		
283-287		
284-288		
285-289		
286-290		
287-291		
288-292		
289-293		
290-294		
291-295		
292-296		
293-297		
294-298		
295-299		
296-300		
297-301		
298-302		
299-303		
300-304		
301-305		
302-306		
303-307		
304-308		
305-309		
306-310		
307-311		
308-312		
309-313		
310-314		
311-315		
312-316		
313-317		
314-318		
315-319		
316-320		
317-321		
318-322		
319-323		
320-324		
321-325		
322-326		
323-327		
324-328		
325-329		
326-330		
327-331		
328-332		
329-333		
330-334		
331-335		
332-336		
333-337		
334-338		
335-339		
336-340		
337-341		
338-342		
339-343		
340-344		
341-345		
342-346		
343-347		
344-348		
345-349		
346-350		
347-351		
348-352		
349-353		
350-354		
351-355		
352-356		
353-357		
354-358		
355-359		
356-360		
357-361		
358-362		
359-363		
360-364		
361-365		
362-366		
363-367		
364-368		
365-369		
366-370		
367-371		
368-372		
369-373		
370-374		
371-375		
372-376		
373-377		
374-378		
375-380		
376-384		
377-386		
378-387		
379-388		
380-389		
381-390		
382-391		
383-390		
384-391		
385-392		
386-393		
387-394		
388-395		
389-396		
390-397		
391-398		
392-399		
393-400		
394-401		
395-402		
396-403		
397-404		
398-405		
399-406		
400-407		
401-408		
402-409		
403-410		
404-411		
405-412		
406-413		
407-414		
408-415		
409-416		
410-417		
411-418		
412-419		
413-420		
414-421		
415-422		
416-423		
417-424		
418-425		
419-426		
420-427		
421-428		
422-429		
423-430		
424-431		
425-432		
426-433		
427-434		
428-435		
429-436		
430-437		
431-438		
432-439		
433-440		
434-441		
435-442		
436-443		
437-444		
438-445		
439-446		
440-447		
441-448		
442-449		
443-450		
444-451		
445-452		
446-453		
447-454		
448-455		
449-456		
450-457		
451-458		
452-459		
453-460		
454-461		
455-462		
456-463		
457-464		
458-465		
459-466		
460-467		
461-468		
462-469		
463-470		
464-471		
465-472		
466-473		

ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE UNEQR(1M,RM,IR,RR,Q)
DIMENSION R(2,2)
FIR=FLOAT(IR)
F14=FLOAT(IN)
B=1,C
DC 1 K=1,5
EX=EXP(-3*(F14+F12-2,C))+((1.0-EX)*(-2.0*B*(FIR-1.0)))*RM/RR
B=ALOG(EX)/(F1M-F1R)
WRITE (6,101) K,3,14,IR,RY,35
101 FORMAT (1-3,X,2H4<,15,3X,2H5<,19E14.6,3X,3HIM<,15,3X,
2,3,IR=15,3X,34RM=,E14.6,3X,3H32=,E14.6),
1 CCONTINUE
1 DC 2 K=6,25
F1=QM*31VH(G*(F12-1.0))
F2=RR*31VH(B*(F1M-1.0))
DC=F1-F2
C1=RM*(F12-1.0)*COSH(B*(F1R-1.0))-RR*(F1M-1.0)*COSH(B*(F1M-1.0))
C2=F1*(F1R-1.0)**2-F2*(F1M-1.0)**2
DB=5*GL(CLOG(1.0C-CALE(DC))*DBL(D2)/DBL(D1)**2)*DBL(D1)/
2 DBL(D2)
B=B+DB
WRITE (6,152) K,32,3
152 FORMAT (14G.3X,2H4<,15,3X,3H32=,1PE14.6,3X,2H8<,E14.6)
IF (ABS(DB)-1.CE-7)>3.2
2 CCONTINUE
3 A=RR/SINH(3*(FIR-1,C))
DC 4 I=1,14
4 R(I)=A*SINH(B*FLOAT(I-1))
4 RETURN
END

```

## ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE PLOTS (X,Y1,Y2,Y3,N1,I1,I2,ND,K1,K2,K3,XMIN,XMAX,
                  YMIN,YMAX)
  PURPOSE - TO PLOT A GRAPH WITH ONE INDEPENDENT VARIABLE AND UP
  TO 9 DEPENDENT VARIABLES. THE INDEPENDENT VARIABLE IS PLOTED ON A
  HORIZONTAL AXIS, THE DEPENDENT ONES ON A VERTICAL AXIS. WHICH
  IS 132 PRINT POSITIONS, HEIGHT IS 50.
  PARAMETER USAGE,
  NUMBER OF OBSERVATIONS (INDEPENDENT + DEPENDENT)
  NUMBER OF X, Y1, Y2, Y3, XMIN, YMIN, MAXIMUM AND MINIMUM VALUES OF THE INDEPENDENT PLOT
  AND DEPENDENT VARIABLES TO BE USED IN THE PLOT.
  IF XMAX = XMIN, THE PROGRAM CALCULATES ITS OWN MAXIMUM AND MINIMUM.
  KPS PLOTTING SYMBOL FOR LTH VARIABLE. AAC,I,L,PLOT0140
  REQUIREDC SUBROUTINES SCAL
  DIMENSION: X(I,J),Y1(I,J),Y2(I,J),Y3(I,J),A(800),KPS(4)
  DATA KJ/H=/
  N=I2-I1+1
  X=N+1
  KPS(1)=<>0
  KPS(2)=<>1
  KPS(3)=<>2
  KPS(4)=<>3
  DC 1 I=I1, N
  J=I+1-I-1
  L2=I+N
  L3=I+2*N
  L4=I+3*N
  A(I1)=X(J)
  A(I2)=Y2(J)
  A(I3)=Y1(J)
  A(I4)=Y3(J)
  XLAX=XMAX
  XLMIN=XMIN
  YLAX=YMAX
  YLMIN=YMIN
  EXTERNAL BLANK
  FUNC=3

```

```
CALL PLOT (C,A,N,V,YFUNC,XLAX,XLIN,YLAX,YLIN,KPS)
RETURN
END
```

```
PLOT0400
PLOT0410
PLOT0420
```

### ONE DIMENSIONAL GAS PARTICLE FLOW

```
SUBROUTINE BLANK (X,Y)
Y=5.0
RETURN
END
```

```
BLAND0010
BLAND0020
BLAND0030
BLAND0040
```

## ONE DIMENSIONAL GAS PARTICLE FLOW

SUBROUTINE PLOT (TC, N, N, FUNC, XLAX, XLIN, YLIN, KFS)  
 PURPOSE - TO PLOT A GRAPH WITH ONE INDEPENDENT VARIABLE AND UP  
 TO 9 DEPENDENT VARIABLES, WITH THE ADDITIONAL ABILITY TO PLOT A  
 CALCULATED CURVE. THE INDEPENDENT VARIABLE IS PLOTTED ON A  
 HORIZONTAL AXIS, THE DEPENDENT VALUES ON A VERTICAL AXIS. WIDTH  
 IS 120 POINT POSITIONS, HEIGHT IS 50, EVERY POINT OF EACH  
 DEPENDENT VARIABLE IS INDICATED BY A NUMBER (1-9). WHILE THE  
 CALCULATED POINTS ARE INDICATED BY ASTERISKS.  
 PARAMETER USAGE:  
 TC = FIXED POINT NUMBER, UP TO 3 DIGITS, PRINTED AS THE  
 CHART NUMBER  
 N = NUMBER OF POSITIONS CONTAIN THE INDEPENDENT  
 VARIABLE, AND WHOSE NEXT N SETS OF N POSITIONS CONTAIN  
 THE DEPENDENT VARIABLES  
 N = NUMBER OF OBSERVATIONS  
 N = NUMBER OF VARIABLES (INDEPENDENT + DEPENDENT)

NFUNC GREATER THAN ZERO IF A CALCULATED CURVE IS TO BE  
 PRINTED  
 FUNC SUBROUTINE TO GENERATE CALCULATED CURVE, IF ONE WANTED.  
 N = A FIXED POINT NUMBER, UP TO 3 DIGITS, PRINTED AS THE  
 CHART NUMBER  
 N = NUMBER OF POSITIONS CONTAIN THE INDEPENDENT  
 VARIABLE, AND WHOSE NEXT N SETS OF N POSITIONS CONTAIN  
 THE DEPENDENT VARIABLES  
 N = NUMBER OF OBSERVATIONS  
 N = NUMBER OF VARIABLES (INDEPENDENT + DEPENDENT)

XLAX, XLIN, YLIN, MAXIMUM AND MINIMUM VALUES OF THE  
 XAXIS, YAXIS, AND YMIN FOR THE INDEPENDENT VARIABLE,  
 WHERE X IS GIVEN TO SURROUND IN A NODDY RETURNED.  
 ELSE IS A DUMMY, PROCEDURE CALLING PLOT MUST HAVE A.,  
 EXTRAS, FUNC, SUBROUTINE TO CALL BY CALL FUNC (X,A),  
 WHERE X IS CALCULATED VARIABLE FOR DATA IN FIRST ARRAY,  
 KFS(1) IS PLOTTING SWAG FOR DATA IN FIRST ARRAY,  
 KFS(2) IS PLOTTING SWAG FOR DATA IN SECOND ARRAY,  
 CALC IS 1 LASER THAT MAXX THIS PREVENTS SLOP OVER INTO  
 NEXT LOCATION. LOOK AROUND C4D = 950 TO SEE WHAT I MEAN,  
 CALC IS WHERE CALCULATED FUNCTION GOES.

REQURED SUBROUTINES, FUNC (IF USED), AND SCAL.  
 SCAL IS WHERE CALCULATED FUNCTION GOES.  
 DATA K/1/H /  
 EQUADRATIC (OUT11,APR11))  
 113 FORMAT(1H1,0DN,74 CHART 13)  
 114 FORMAT(1H1,0DN,12X,2-,13121,1H1-)

```

2 FORMAT (1H ,1P2E12.3,2H+ ,131A11,1H+,E12.3)
3
4 FCN41T (1H ,1I5,5X,1E10,3,19E10,3) .. . ,1H+
5 PRINT CH41T NC .
6
7 FCN41T (1H ,1I5,5X,1E10,3,19E10,3)
8
9 IF (X'IAK - X'L') > 20,10,20
10 IF (X'IAK - X'L') < -20,10,20
11 COUNT = A(1)
12 IF (A(j) - XMAX) > 25,15,14
13 XMAX = X(j)
14 XMIN = X(j)
15 COUNT = A(1)
16 IF (A(j) - XMIN) < -25,15,12
17 XMIN = A(j)
18 COUNT = 15
19 COUNT = 15
20
21 COUNT = A(j)
22 IF (A(j) - XMAX) < -25,15,14
23 XMAX = X(j)
24 XMIN = X(j)
25 COUNT = A(1)
26
27 FCN41T (1H ,1I5,5X,1E10,3,19E10,3)
28
29 IF NEXTEENES OF X GIVEN, FIND THEM
30 DIVISION. IOUT(100),XAR(11),ACCO),CALC(102),KPS(4)
31
32 PLOT0400
33 PLOT0410
34 PLOT0420
35 PLOT0430
36 PLOT0440
37 PLOT0450
38 PLOT0460
39 PLOT0470
40 PLOT0480
41 PLOT0490
42 PLOT0500
43 PLOT0510
44 PLOT0520
45 PLOT0530
46 PLOT0540
47 PLOT0550
48 PLOT0560
49 PLOT0570
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

2 IF CALCULATED CURVE WANTED GET VALUES BETWEEN XMIN AND XMAX
3 IF (NEUAC) 213,0,215,0,211
4 F = XMIN
5 Z = 1
6 Z = 1
7 CALL, EFUNC(F,C-LC(C-P))
8 IF (Z = 2) MAX(212,213,214)
9 F = Z + 1
10 GO TO 213
11 CONTINUE
12 PRINT PNT AT MAXIMUM Y
13 YPR = YMAX
14 CLEAR PRNT LINE
15 GO SS JP = 1,0,01
16 TPUT(JP) 26
17 IF C-NCURV SET UP POINTS
18 IF (NEUAC) 214,0,216,0,215
19 F = XMAX
20 PLOT970
21 PLOT0940
22 PLOT990
23 PLOT1000
24 PLOT1010
25 PLOT1020
26 PLOT1030
27 PLOT1040
28 PLOT1050
29 PLOT1060
30 PLOT1070
31 PLOT1080
32 PLOT1090
33 PLOT1100
34 PLOT1110
35 PLOT1120
36 PLOT1130
37 PLOT1140

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

C SCAN ALL VALUES OF Y FOR X BETWEEN XMIN AND XMAX
C
C JP = POINT WITHIN HALF A SCALE OF PRINT POSITION
C 223 IF (ASSC(YP)-CALC(JP)) - .5 * YSCAL) 216,217,218
C IF EXACTLY BETWEEN PRINT POSITIONS ONLY PRINT IT ONCE
C 217 IF (YFR - CALC (JP)) 218,219,216
C BELIEVE IT OR NOT THIS IS AN ASTERISK (NUMBER TOO LARGE TO WRITE
C AS ONE NUMBER)
C 215 IOUT(JP) =EXP(1)
C 215 IF (F - XMAX) 219,214,214
C 215 JP = JP + 1
C F = F + XSCAL
C GO TO 223
C IN EACH SET OF DEPENDENT VARIABLES
C IF NC POINTS NATED
C 214 IF (N) 70,70,300
C 353 G0 222; J = 215
C 222 L = 1;
C CALCULATE SUBSCRIPT FOR A
C LL = (J - 1) * N + L
C IS IT WITHIN HALF A SCALE OF PRINT POSITION
C 223 IF (ASSC(YP - A(LL)) - .5 * YSCAL) 223,224,225
C IF EXACTLY HALF WAY BETWEEN, PRINT ONLY ONCE
C 224 IF (YFR - A(LL)) 225,223,223
C F1.5 TO TOTAL POSITION
C 223 F1F = (A(LL) - X1), / XSCAL + 1.5
C JFS=IF(K(JP)) EXP(S(J))
C IF OFF Graph, FORSET IT
C 226 IF (JP - 1) 225,226,226
C THIS GIVES 1,2,3 ETC, FOR J=2,3,4 ETC
C 227 IOUT(JP) =EXP(S(J));
C 228 CONTINUE
C 225 CONTINUE
C 222 CONTINUE
C 221 CONTINUE
C 220 COUNT = COUNT +1
C PRINT VALUE ON VERTICAL AXIS EVERY FIVE POSITIONS
C IF (COUNT - 5) 120,119,120
C 121 WRITE (6,112) (IOUT(JP), JP=1,101)

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

23: IF (455(XPR(JB+1)) = .5*XSCAL) 231,231,90
23: XPR(JB+1) = 0.
93: COT11UE
93: MPR11(16,8) (XPR(JP),JPR11)
E751N
C

```

ONE DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE SCAL (XSCAL,XMAX,XMIN)
PURPOSE: GIVEN A(X) SCALE AND END POINTS, GET ROUNDED VALUES,
          F=LOG10(XSCAL), I=2000001
      FIND NEXT LOWEST POWER OF 10,
      IF (F) 1,2,2 STOP FORTRAN FROM ROUNDING UP
      1  JP=-1\1-(F-1.0)
      2  JPUT=INT(F)
      3  PRINT *,"I= ",JPUT," JUST LARGER THAN ",I," XSCAL = ",OF FORM 1,2,2,5,2,OF 10
      4  IF (NEXT) STOP
      5  GO TO 2
      6  IF (F-XSCAL) 5,4,4
      7  F=F+1
      8  IF (F-XSCAL) 5,4,4
      9  JPUT=INT(XSCAL/XSCAL)
      10  IF (JPUT*XSCAL/XSCAL)-1.0E9) 8,21,11
      11  SET SCAL MULTIPLES OF SCALE
      12  IF (F-XSCAL) 13,14,15
      13  F=XSCAL*FLOAT(JP)
      14  XIN=F
      15  JPUT=1
      16  IF (F-XSCAL) 14,15,15
      17  IF (F-XSCAL) 12,18,19
      18  RETURN
      19  END

```

ONE DIMENSIONAL SDS PARTICLE FILE

```

SUBROUTINE DSDC2
      PARAMETER NDC=20
      COMMON /DSDC/ NDC,NDCC,NDCC1,NDCC2,NDCC3,NDCC4,NDCC5,
     1          NDCC6,NDCC7,NDCC8,NDCC9,NDCC10,NDCC11,NDCC12,
     2          NDCC13,NDCC14,NDCC15,NDCC16,NDCC17,NDCC18,NDCC19,
     3          NDCC20,NDCC21,NDCC22,NDCC23,NDCC24,NDCC25,NDCC26,
     4          NDCC27,NDCC28,NDCC29,NDCC30,NDCC31,NDCC32,NDCC33,
     5          NDCC34,NDCC35,NDCC36,NDCC37,NDCC38,NDCC39,NDCC40,
     6          NDCC41,NDCC42,NDCC43,NDCC44,NDCC45,NDCC46,NDCC47,
     7          NDCC48,NDCC49,NDCC50,NDCC51,NDCC52,NDCC53,NDCC54,
     8          NDCC55,NDCC56,NDCC57,NDCC58,NDCC59,NDCC60,NDCC61,
     9          NDCC62,NDCC63,NDCC64,NDCC65,NDCC66,NDCC67,NDCC68,
    10         NDCC69,NDCC70,NDCC71,NDCC72,NDCC73,NDCC74,NDCC75,
    11         NDCC76,NDCC77,NDCC78,NDCC79,NDCC80,NDCC81,NDCC82,
    12         NDCC83,NDCC84,NDCC85,NDCC86,NDCC87,NDCC88,NDCC89,
    13         NDCC90,NDCC91,NDCC92,NDCC93,NDCC94,NDCC95,NDCC96,
    14         NDCC97,NDCC98,NDCC99,NDCC100,NDCC101,NDCC102,NDCC103,
    15         NDCC104,NDCC105,NDCC106,NDCC107,NDCC108,NDCC109,NDCC110,
    16         NDCC111,NDCC112,NDCC113,NDCC114,NDCC115,NDCC116,NDCC117,
    17         NDCC118,NDCC119,NDCC120,NDCC121,NDCC122,NDCC123,NDCC124,
    18         NDCC125,NDCC126,NDCC127,NDCC128,NDCC129,NDCC130,NDCC131,
    19         NDCC132,NDCC133,NDCC134,NDCC135,NDCC136,NDCC137,NDCC138,
    20         NDCC139,NDCC140,NDCC141,NDCC142,NDCC143,NDCC144,NDCC145,
    21         NDCC146,NDCC147,NDCC148,NDCC149,NDCC150,NDCC151,NDCC152,
    22         NDCC153,NDCC154,NDCC155,NDCC156,NDCC157,NDCC158,NDCC159,
    23         NDCC160,NDCC161,NDCC162,NDCC163,NDCC164,NDCC165,NDCC166,
    24         NDCC167,NDCC168,NDCC169,NDCC170,NDCC171,NDCC172,NDCC173,
    25         NDCC174,NDCC175,NDCC176,NDCC177,NDCC178,NDCC179,NDCC180,
    26         NDCC181,NDCC182,NDCC183,NDCC184,NDCC185,NDCC186,NDCC187,
    27         NDCC188,NDCC189,NDCC190,NDCC191,NDCC192,NDCC193,NDCC194,
    28         NDCC195,NDCC196,NDCC197,NDCC198,NDCC199,NDCC200,NDCC201,
    29         NDCC202,NDCC203,NDCC204,NDCC205,NDCC206,NDCC207,NDCC208,
    30         NDCC209,NDCC210,NDCC211,NDCC212,NDCC213,NDCC214,NDCC215,
    31         NDCC216,NDCC217,NDCC218,NDCC219,NDCC220,NDCC221,NDCC222,
    32         NDCC223,NDCC224,NDCC225,NDCC226,NDCC227,NDCC228,NDCC229,
    33         NDCC230,NDCC231,NDCC232,NDCC233,NDCC234,NDCC235,NDCC236,
    34         NDCC237,NDCC238,NDCC239,NDCC240,NDCC241,NDCC242,NDCC243,
    35         NDCC244,NDCC245,NDCC246,NDCC247,NDCC248,NDCC249,NDCC250,
    36         NDCC251,NDCC252,NDCC253,NDCC254,NDCC255,NDCC256,NDCC257,
    37         NDCC258,NDCC259,NDCC260,NDCC261,NDCC262,NDCC263,NDCC264,
    38         NDCC265,NDCC266,NDCC267,NDCC268,NDCC269,NDCC270,NDCC271,
    39         NDCC272,NDCC273,NDCC274,NDCC275,NDCC276,NDCC277,NDCC278,
    40         NDCC279,NDCC280,NDCC281,NDCC282,NDCC283,NDCC284,NDCC285,
    41         NDCC286,NDCC287,NDCC288,NDCC289,NDCC290,NDCC291,NDCC292,
    42         NDCC293,NDCC294,NDCC295,NDCC296,NDCC297,NDCC298,NDCC299,
    43         NDCC300,NDCC301,NDCC302,NDCC303,NDCC304,NDCC305,NDCC306,
    44         NDCC307,NDCC308,NDCC309,NDCC310,NDCC311,NDCC312,NDCC313,
    45         NDCC314,NDCC315,NDCC316,NDCC317,NDCC318,NDCC319,NDCC320,
    46         NDCC321,NDCC322,NDCC323,NDCC324,NDCC325,NDCC326,NDCC327,
    47         NDCC328,NDCC329,NDCC330,NDCC331,NDCC332,NDCC333,NDCC334,
    48         NDCC335,NDCC336,NDCC337,NDCC338,NDCC339,NDCC340,NDCC341,
    49         NDCC342,NDCC343,NDCC344,NDCC345,NDCC346,NDCC347,NDCC348,
    50         NDCC349,NDCC350,NDCC351,NDCC352,NDCC353,NDCC354,NDCC355,
    51         NDCC356,NDCC357,NDCC358,NDCC359,NDCC360,NDCC361,NDCC362,
    52         NDCC363,NDCC364,NDCC365,NDCC366,NDCC367,NDCC368,NDCC369,
    53         NDCC370,NDCC371,NDCC372,NDCC373,NDCC374,NDCC375,NDCC376,
    54         NDCC377,NDCC378,NDCC379,NDCC380,NDCC381,NDCC382,NDCC383,
    55         NDCC384,NDCC385,NDCC386,NDCC387,NDCC388,NDCC389,NDCC390,
    56         NDCC391,NDCC392,NDCC393,NDCC394,NDCC395,NDCC396,NDCC397,
    57         NDCC398,NDCC399,NDCC400,NDCC401,NDCC402,NDCC403,NDCC404,
    58         NDCC405,NDCC406,NDCC407,NDCC408,NDCC409,NDCC410,NDCC411,
    59         NDCC412,NDCC413,NDCC414,NDCC415,NDCC416,NDCC417,NDCC418,
    60         NDCC419,NDCC420,NDCC421,NDCC422,NDCC423,NDCC424,NDCC425,
    61         NDCC426,NDCC427,NDCC428,NDCC429,NDCC430,NDCC431,NDCC432,
    62         NDCC433,NDCC434,NDCC435,NDCC436,NDCC437,NDCC438,NDCC439,
    63         NDCC440,NDCC441,NDCC442,NDCC443,NDCC444,NDCC445,NDCC446,
    64         NDCC447,NDCC448,NDCC449,NDCC450,NDCC451,NDCC452,NDCC453,
    65         NDCC454,NDCC455,NDCC456,NDCC457,NDCC458,NDCC459,NDCC460,
    66         NDCC461,NDCC462,NDCC463,NDCC464,NDCC465,NDCC466,NDCC467,
    67         NDCC468,NDCC469,NDCC470,NDCC471,NDCC472,NDCC473,NDCC474,
    68         NDCC475,NDCC476,NDCC477,NDCC478,NDCC479,NDCC479,NDCC480,
    69         NDCC481,NDCC482,NDCC483,NDCC484,NDCC485,NDCC486,NDCC487,
    70         NDCC488,NDCC489,NDCC490,NDCC491,NDCC492,NDCC493,NDCC494,
    71         NDCC495,NDCC496,NDCC497,NDCC498,NDCC499,NDCC500,NDCC501,
    72         NDCC502,NDCC503,NDCC504,NDCC505,NDCC506,NDCC507,NDCC508,
    73         NDCC509,NDCC510,NDCC511,NDCC512,NDCC513,NDCC514,NDCC515,
    74         NDCC516,NDCC517,NDCC518,NDCC519,NDCC520,NDCC521,NDCC522,
    75         NDCC523,NDCC524,NDCC525,NDCC526,NDCC527,NDCC528,NDCC529,
    76         NDCC530,NDCC531,NDCC532,NDCC533,NDCC534,NDCC535,NDCC536,
    77         NDCC537,NDCC538,NDCC539,NDCC540,NDCC541,NDCC542,NDCC543,
    78         NDCC544,NDCC545,NDCC546,NDCC547,NDCC548,NDCC549,NDCC550,
    79         NDCC551,NDCC552,NDCC553,NDCC554,NDCC555,NDCC556,NDCC557,
    80         NDCC558,NDCC559,NDCC560,NDCC561,NDCC562,NDCC563,NDCC564,
    81         NDCC565,NDCC566,NDCC567,NDCC568,NDCC569,NDCC569,NDCC570,
    82         NDCC571,NDCC572,NDCC573,NDCC574,NDCC575,NDCC576,NDCC577,
    83         NDCC578,NDCC579,NDCC580,NDCC581,NDCC582,NDCC583,NDCC584,
    84         NDCC585,NDCC586,NDCC587,NDCC588,NDCC589,NDCC589,NDCC590,
    85         NDCC591,NDCC592,NDCC593,NDCC594,NDCC595,NDCC596,NDCC597,
    86         NDCC598,NDCC599,NDCC600,NDCC601,NDCC602,NDCC603,NDCC604,
    87         NDCC605,NDCC606,NDCC607,NDCC608,NDCC609,NDCC609,NDCC610,
    88         NDCC611,NDCC612,NDCC613,NDCC614,NDCC615,NDCC616,NDCC617,
    89         NDCC618,NDCC619,NDCC620,NDCC621,NDCC622,NDCC623,NDCC624,
    90         NDCC625,NDCC626,NDCC627,NDCC628,NDCC629,NDCC629,NDCC630,
    91         NDCC631,NDCC632,NDCC633,NDCC634,NDCC635,NDCC636,NDCC637,
    92         NDCC638,NDCC639,NDCC640,NDCC641,NDCC642,NDCC643,NDCC644,
    93         NDCC645,NDCC646,NDCC647,NDCC648,NDCC649,NDCC649,NDCC650,
    94         NDCC651,NDCC652,NDCC653,NDCC654,NDCC655,NDCC656,NDCC657,
    95         NDCC658,NDCC659,NDCC660,NDCC661,NDCC662,NDCC663,NDCC664,
    96         NDCC665,NDCC666,NDCC667,NDCC668,NDCC669,NDCC669,NDCC670,
    97         NDCC671,NDCC672,NDCC673,NDCC674,NDCC675,NDCC676,NDCC677,
    98         NDCC678,NDCC679,NDCC680,NDCC681,NDCC682,NDCC683,NDCC684,
    99         NDCC685,NDCC686,NDCC687,NDCC688,NDCC689,NDCC689,NDCC690,
   100        NDCC691,NDCC692,NDCC693,NDCC694,NDCC695,NDCC696,NDCC697,
   101        NDCC698,NDCC699,NDCC700,NDCC701,NDCC702,NDCC703,NDCC704,
   102        NDCC705,NDCC706,NDCC707,NDCC708,NDCC709,NDCC709,NDCC710,
   103        NDCC711,NDCC712,NDCC713,NDCC714,NDCC715,NDCC716,NDCC717,
   104        NDCC718,NDCC719,NDCC720,NDCC721,NDCC722,NDCC723,NDCC724,
   105        NDCC725,NDCC726,NDCC727,NDCC728,NDCC729,NDCC729,NDCC730,
   106        NDCC731,NDCC732,NDCC733,NDCC734,NDCC735,NDCC736,NDCC737,
   107        NDCC738,NDCC739,NDCC740,NDCC741,NDCC742,NDCC743,NDCC744,
   108        NDCC745,NDCC746,NDCC747,NDCC748,NDCC749,NDCC749,NDCC750,
   109        NDCC751,NDCC752,NDCC753,NDCC754,NDCC755,NDCC756,NDCC757,
   110        NDCC758,NDCC759,NDCC760,NDCC761,NDCC762,NDCC763,NDCC764,
   111        NDCC765,NDCC766,NDCC767,NDCC768,NDCC769,NDCC769,NDCC770,
   112        NDCC771,NDCC772,NDCC773,NDCC774,NDCC775,NDCC776,NDCC777,
   113        NDCC778,NDCC779,NDCC780,NDCC781,NDCC782,NDCC783,NDCC784,
   114        NDCC785,NDCC786,NDCC787,NDCC788,NDCC789,NDCC789,NDCC790,
   115        NDCC791,NDCC792,NDCC793,NDCC794,NDCC795,NDCC796,NDCC797,
   116        NDCC798,NDCC799,NDCC800,NDCC801,NDCC802,NDCC803,NDCC804,
   117        NDCC805,NDCC806,NDCC807,NDCC808,NDCC809,NDCC809,NDCC810,
   118        NDCC811,NDCC812,NDCC813,NDCC814,NDCC815,NDCC816,NDCC817,
   119        NDCC818,NDCC819,NDCC820,NDCC821,NDCC822,NDCC823,NDCC824,
   120        NDCC825,NDCC826,NDCC827,NDCC828,NDCC829,NDCC829,NDCC830,
   121        NDCC831,NDCC832,NDCC833,NDCC834,NDCC835,NDCC836,NDCC837,
   122        NDCC838,NDCC839,NDCC840,NDCC841,NDCC842,NDCC843,NDCC844,
   123        NDCC845,NDCC846,NDCC847,NDCC848,NDCC849,NDCC849,NDCC850,
   124        NDCC851,NDCC852,NDCC853,NDCC854,NDCC855,NDCC856,NDCC857,
   125        NDCC858,NDCC859,NDCC860,NDCC861,NDCC862,NDCC863,NDCC864,
   126        NDCC865,NDCC866,NDCC867,NDCC868,NDCC869,NDCC869,NDCC870,
   127        NDCC871,NDCC872,NDCC873,NDCC874,NDCC875,NDCC876,NDCC877,
   128        NDCC878,NDCC879,NDCC880,NDCC881,NDCC882,NDCC883,NDCC884,
   129        NDCC885,NDCC886,NDCC887,NDCC888,NDCC889,NDCC889,NDCC890,
   130        NDCC891,NDCC892,NDCC893,NDCC894,NDCC895,NDCC896,NDCC897,
   131        NDCC898,NDCC899,NDCC900,NDCC901,NDCC902,NDCC903,NDCC904,
   132        NDCC905,NDCC906,NDCC907,NDCC908,NDCC909,NDCC909,NDCC910,
   133        NDCC911,NDCC912,NDCC913,NDCC914,NDCC915,NDCC916,NDCC917,
   134        NDCC918,NDCC919,NDCC920,NDCC921,NDCC922,NDCC923,NDCC924,
   135        NDCC925,NDCC926,NDCC927,NDCC928,NDCC929,NDCC929,NDCC930,
   136        NDCC931,NDCC932,NDCC933,NDCC934,NDCC935,NDCC936,NDCC937,
   137        NDCC938,NDCC939,NDCC940,NDCC941,NDCC942,NDCC943,NDCC944,
   138        NDCC945,NDCC946,NDCC947,NDCC948,NDCC949,NDCC949,NDCC950,
   139        NDCC951,NDCC952,NDCC953,NDCC954,NDCC955,NDCC956,NDCC957,
   140        NDCC958,NDCC959,NDCC960,NDCC961,NDCC962,NDCC963,NDCC964,
   141        NDCC965,NDCC966,NDCC967,NDCC968,NDCC969,NDCC969,NDCC970,
   142        NDCC971,NDCC972,NDCC973,NDCC974,NDCC975,NDCC976,NDCC977,
   143        NDCC978,NDCC979,NDCC980,NDCC981,NDCC982,NDCC983,NDCC984,
   144        NDCC985,NDCC986,NDCC987,NDCC988,NDCC989,NDCC989,NDCC990,
   145        NDCC991,NDCC992,NDCC993,NDCC994,NDCC995,NDCC996,NDCC997,
   146        NDCC998,NDCC999,NDCC1000,NDCC1001,NDCC1002,NDCC1003,NDCC1004,
   147        NDCC1005,NDCC1006,NDCC1007,NDCC1008,NDCC1009,NDCC1009,NDCC1010,
   148        NDCC1011,NDCC1012,NDCC1013,NDCC1014,NDCC1015,NDCC1016,NDCC1017,
   149        NDCC1018,NDCC1019,NDCC1020,NDCC1021,NDCC1022,NDCC1023,NDCC1024,
   150        NDCC1025,NDCC1026,NDCC1027,NDCC1028,NDCC1029,NDCC1029,NDCC1030,
   151        NDCC1031,NDCC1032,NDCC1033,NDCC1034,NDCC1035,NDCC1036,NDCC1037,
   152        NDCC1038,NDCC1039,NDCC1040,NDCC1041,NDCC1042,NDCC1043,NDCC1044,
   153        NDCC1045,NDCC1046,NDCC1047,NDCC1048,NDCC1049,NDCC1049,NDCC1050,
   154        NDCC1051,NDCC1052,NDCC1053,NDCC1054,NDCC1055,NDCC1056,NDCC1057,
   155        NDCC1058,NDCC1059,NDCC1060,NDCC1061,NDCC1062,NDCC1063,NDCC1064,
   156        NDCC1065,NDCC1066,NDCC1067,NDCC1068,NDCC1069,NDCC1069,NDCC1070,
   157        NDCC1071,NDCC1072,NDCC1073,NDCC1074,NDCC1075,NDCC1076,NDCC1077,
   158        NDCC1078,NDCC1079,NDCC1080,NDCC1081,NDCC1082,NDCC1083,NDCC1084,
   159        NDCC1085,NDCC1086,NDCC1087,NDCC1088,NDCC1089,NDCC1089,NDCC1090,
   160        NDCC1091,NDCC1092,NDCC1093,NDCC1094,NDCC1095,NDCC1096,NDCC1097,
   161        NDCC1098,NDCC1099,NDCC1100,NDCC1101,NDCC1102,NDCC1103,NDCC1104,
   162        NDCC1105,NDCC1106,NDCC1107,NDCC1108,NDCC1109,NDCC1109,NDCC1110,
   163        NDCC1111,NDCC1112,NDCC1113,NDCC1114,NDCC1115,NDCC1116,NDCC1117,
   164        NDCC1118,NDCC1119,NDCC1120,NDCC1121,NDCC1122,NDCC1123,NDCC1124,
   165        NDCC1125,NDCC1126,NDCC1127,NDCC1128,NDCC1129,NDCC1129,NDCC1130,
   166        NDCC1131,NDCC1132,NDCC1133,NDCC1134,NDCC1135,NDCC1136,NDCC1137,
   167        NDCC1138,NDCC1139,NDCC1140,NDCC1141,NDCC1142,NDCC1143,NDCC1144,
   168        NDCC1145,NDCC1146,NDCC1147,NDCC1148,NDCC1149,NDCC1149,NDCC1150,
   169        NDCC1151,NDCC1152,NDCC1153,NDCC1154,NDCC1155,NDCC1156,NDCC1157,
   170        NDCC1158,NDCC1159,NDCC1160,NDCC1161,NDCC1162,NDCC1163,NDCC1164,
   171        NDCC1165,NDCC1166,NDCC1167,NDCC1168,NDCC1169,NDCC1169,NDCC1170,
   172        NDCC1171,NDCC1172,NDCC1173,NDCC1174,NDCC1175,NDCC1176,NDCC1177,
   173        NDCC1178,NDCC1179,NDCC1180,NDCC1181,NDCC1182,NDCC1183,NDCC1184,
   174        NDCC1185,NDCC1186,NDCC1187,NDCC1188,NDCC1189,NDCC1189,NDCC1190,
   175        NDCC1191,NDCC1192,NDCC1193,NDCC1194,NDCC1195,NDCC1196,NDCC1197,
   176        NDCC1198,NDCC1199,NDCC1200,NDCC1201,NDCC1202,NDCC1203,NDCC1204,
   177        NDCC1205,NDCC1206,NDCC1207,NDCC1208,NDCC1209,NDCC1209,NDCC1210,
   178        NDCC1211,NDCC1212,NDCC1213,NDCC1214,NDCC1215,NDCC1216,NDCC1217,
   179        NDCC1218,NDCC1219,NDCC1220,NDCC1221,NDCC1222,NDCC1223,NDCC1224,
   180        NDCC1225,NDCC1226,NDCC1227,NDCC1228,NDCC1229,NDCC1229,NDCC1230,
   181        NDCC1231,NDCC1232,NDCC1233,NDCC1234,NDCC1235,NDCC1236,NDCC1237,
   182        NDCC1238,NDCC1239,NDCC1240,NDCC1241,NDCC1242,NDCC1243,NDCC1244,
   183        NDCC1245,NDCC1246,NDCC1247,NDCC1248,NDCC1249,NDCC1249,NDCC1250,
   184        NDCC1251,NDCC1252,NDCC1253,NDCC1254,NDCC1255,NDCC1256,NDCC1257,
   185        NDCC1258,NDCC1259,NDCC1260,NDCC1261,NDCC1262,NDCC1263,NDCC1264,
   186        NDCC1265,NDCC1266,NDCC1267,NDCC1268,NDCC1269,NDCC1269,NDCC1270,
   187        NDCC1271,NDCC1272,NDCC1273,NDCC1274,NDCC1275,NDCC1276,NDCC1277,
   188        NDCC1278,NDCC1279,NDCC1280,NDCC1281,NDCC1282,NDCC1283,NDCC1284,
   189        NDCC1285,NDCC1286,NDCC1287,NDCC1288,NDCC1289,NDCC1289,NDCC1290,
   190        NDCC1291,NDCC1292,NDCC1293,NDCC1294,NDCC1295,NDCC1296,NDCC1297,
   191        NDCC1298,NDCC1299,NDCC1300,NDCC1301,NDCC1302,NDCC1303,NDCC1304,
   192        NDCC1305,NDCC1306,NDCC1307,NDCC1308,NDCC1309,NDCC1309,NDCC1310,
   193        NDCC1311,NDCC1312,NDCC1313,NDCC1314,NDCC1315,NDCC1316,NDCC1317,
   194        NDCC1318,NDCC1319,NDCC1320,NDCC1321,NDCC1322,NDCC1323,NDCC1324,
   195        NDCC1325,NDCC1326,NDCC1327,NDCC1328,NDCC1329,NDCC1329,NDCC1330,
   196        NDCC1331,NDCC1332,NDCC1333,NDCC1334,NDCC1335,NDCC1336,NDCC1337,
   197        NDCC1338,NDCC1339,NDCC1340,NDCC1341,NDCC1342,NDCC1343,NDCC1344,
   198        NDCC1345,NDCC1346,NDCC1347,NDCC1348,NDCC1349,NDCC1349,NDCC1350,
   199        NDCC1351,NDCC1352,NDCC1353,NDCC1354,NDCC1355,NDCC1356,NDCC1357,
   200        NDCC1358,NDCC1359,NDCC1360,NDCC1361,NDCC1362,NDCC1363,NDCC1364,
   201        NDCC1365,NDCC1366,NDCC1367,NDCC1368,NDCC1369,NDCC1369,NDCC1370,
   202        NDCC1371,NDCC1372,NDCC1373,NDCC1374,NDCC1375,NDCC1376,NDCC1377,
   203        NDCC1378,NDCC1379,NDCC1380,NDCC1381,NDCC1382,NDCC1383,NDCC1384,
   204        NDCC1385,NDCC1386,NDCC1387,NDCC1388,NDCC1389,NDCC1389,NDCC1390,
   205        NDCC1391,NDCC1392,NDCC1393,NDCC1394,NDCC1395,NDCC1396,NDCC1397,
   206        NDCC1398,NDCC1399,NDCC1400,NDCC1401,NDCC1402,NDCC1403,NDCC1404,
   207        NDCC1405,NDCC1406,NDCC1407,NDCC1408,NDCC1409,NDCC1409,NDCC1410,
   208        NDCC1411,NDCC1412,NDCC1413,NDCC1414,NDCC1415,NDCC1416,NDCC1417,
   209        NDCC1418,NDCC1419,NDCC1420,NDCC1421,NDCC1422,NDCC1423,NDCC1424,
   210        NDCC1425,NDCC1426,NDCC1427,NDCC1428,NDCC1429,NDCC1429,NDCC1430,
   211        NDCC1431,NDCC1432,NDCC1433,NDCC1434,NDCC1435,NDCC1436,NDCC1437,
   212        NDCC1438,NDCC1439,NDCC1440,NDCC1441,NDCC1442,NDCC1443,NDCC1444,
   213        NDCC1445,NDCC1446,NDCC1447,NDCC1448,NDCC1449,NDCC1449,NDCC1450,
   214        NDCC1451,NDCC1452,NDCC1453,NDCC1454,NDCC1455,NDCC1456,NDCC1457,
   215        NDCC1458,NDCC1459,NDCC1460,NDCC1461,NDCC1462,NDCC1463,NDCC1464,
   216        NDCC1465,NDCC1466,NDCC1467,NDCC1468,NDCC1469,NDCC1469,NDCC1470,
   217        NDCC1471,NDCC1472,NDCC1473,NDCC1474,NDCC1475,NDCC1476,NDCC1477,
   218        NDCC1478,NDCC1479,NDCC1480,NDCC1481,NDCC1482,NDCC1483,NDCC1484,
   219        NDCC1485,NDCC1486,NDCC1487,NDCC1488,NDCC1489,NDCC1489,NDCC1490,
   220        NDCC1491,NDCC1492,NDCC1493,NDCC1494,NDCC1495,NDCC1496,NDCC1497,
   221        NDCC1498,NDCC1499,NDCC1500,NDCC1501,NDCC1502,NDCC1503,NDCC1504,
   222        NDCC1505,NDCC1506,NDCC1507,NDCC1508,NDCC1509,NDCC1509,NDCC1510,
   223        NDCC1511,NDCC1512,NDCC1513,NDCC1514,NDCC1515,NDCC1516,NDCC1517,
   224        NDCC1518,NDCC1519,NDCC1520,NDCC1521,NDCC1522,NDCC1523,NDCC1524,
   225        NDCC1525,NDCC1526,NDCC1527,NDCC1528,NDCC1529,NDCC1529,NDCC1530,
   226        NDCC1531,NDCC1532,NDCC1533,NDCC1534,NDCC1535,NDCC1536,NDCC1537,
   227
```

10 GO TO 15  
10 X2=X\*X  
10 X4=X2\*X2  
X8=X4\*X4  
X8=X3\*X2  
15 GO TO (16,17),KS  
16 PCW=1.0/XP  
16 RETURN  
17 POW=XP  
17 RETURN  
END

POW 0400  
POW 0410  
POW 0420  
POW 0430  
POW 0440  
POW 0450  
POW 0460  
POW 0470  
POW 0480  
POW 0490  
POW 0500

ONE DIMENSIONAL GAS PARTICLE FLOW

```

FUNCTION ROOT (X,<1>)
C   ROOT<KTH> ROOT OF X
C   K MUST SATISFY 0 <= K <= N-1
C   DIFFUSION A(LD), C(LD), D(LD)
C   DC(1)=1, DC(2)=2, DC(3)=3, DC(4)=4, DC(5)=5, DC(6)=6
C   DC(7)=7, DC(8)=8, DC(9)=9, DC(10)=10
C   F(X)=FLCAT(A,L)
C   ROOT=0.0
C   RETURN
C   ROOT=X
C   IF (X) 6,7,6
C   6 ROOT=0.0
C   RETURN
C   ROOT=0
C   RETURN
C   IF (X) 1,2,3
C   1 IF (X) 11,12,13
C   12 RETURN
C   13 IF (X) 14,15,16
C   14 IF (X) 17,18,19
C   15 IF (X) 20,21,22
C   16 IF (X) 23,24,25
C   17 IF (X) 26,27,28
C   18 IF (X) 29,30,31
C   19 IF (X) 32,33,34
C   20 IF (X) 35,36,37
C   21 IF (X) 38,39,40
C   22 IF (X) 41,42,43
C   23 IF (X) 44,45,46
C   24 IF (X) 47,48,49
C   25 IF (X) 50,51,52
C   26 IF (X) 53,54,55
C   27 IF (X) 56,57,58
C   28 IF (X) 59,60,61
C   29 IF (X) 62,63,64
C   30 IF (X) 65,66,67
C   31 IF (X) 68,69,70
C   32 IF (X) 71,72,73
C   33 IF (X) 74,75,76
C   34 IF (X) 77,78,79
C   35 IF (X) 80,81,82
C   36 IF (X) 83,84,85
C   37 IF (X) 86,87,88
C   38 IF (X) 89,90,91
C   39 IF (X) 92,93,94
C   40 IF (X) 95,96,97
C   41 IF (X) 98,99,100
C   42 IF (X) 101,102,103
C   43 IF (X) 104,105,106
C   44 IF (X) 107,108,109
C   45 IF (X) 110,111,112
C   46 IF (X) 113,114,115
C   47 IF (X) 116,117,118
C   48 IF (X) 119,120,121
C   49 IF (X) 122,123,124
C   50 IF (X) 125,126,127
C   51 IF (X) 128,129,130
C   52 IF (X) 131,132,133
C   53 IF (X) 134,135,136
C   54 IF (X) 137,138,139
C   55 IF (X) 140,141,142
C   56 IF (X) 143,144,145
C   57 IF (X) 146,147,148
C   58 IF (X) 149,150,151
C   59 IF (X) 152,153,154
C   60 IF (X) 155,156,157
C   61 IF (X) 158,159,160
C   62 IF (X) 161,162,163
C   63 IF (X) 164,165,166
C   64 IF (X) 167,168,169
C   65 IF (X) 170,171,172
C   66 IF (X) 173,174,175
C   67 IF (X) 176,177,178
C   68 IF (X) 179,180,181
C   69 IF (X) 182,183,184
C   70 IF (X) 185,186,187
C   71 IF (X) 188,189,190
C   72 IF (X) 191,192,193
C   73 IF (X) 194,195,196
C   74 IF (X) 197,198,199
C   75 IF (X) 200,201,202
C   76 IF (X) 203,204,205
C   77 IF (X) 206,207,208
C   78 IF (X) 209,210,211
C   79 IF (X) 212,213,214
C   80 IF (X) 215,216,217
C   81 IF (X) 218,219,220
C   82 IF (X) 221,222,223
C   83 IF (X) 224,225,226
C   84 IF (X) 227,228,229
C   85 IF (X) 230,231,232
C   86 IF (X) 233,234,235
C   87 IF (X) 236,237,238
C   88 IF (X) 239,240,241
C   89 IF (X) 242,243,244
C   90 IF (X) 245,246,247
C   91 IF (X) 248,249,250
C   92 IF (X) 251,252,253
C   93 IF (X) 254,255,256
C   94 IF (X) 257,258,259
C   95 IF (X) 260,261,262
C   96 IF (X) 263,264,265
C   97 IF (X) 266,267,268
C   98 IF (X) 269,270,271
C   99 IF (X) 272,273,274
C   100 IF (X) 275,276,277
C   101 IF (X) 278,279,280
C   102 IF (X) 281,282,283
C   103 IF (X) 284,285,286
C   104 IF (X) 287,288,289
C   105 IF (X) 290,291,292
C   106 IF (X) 293,294,295
C   107 IF (X) 296,297,298
C   108 IF (X) 299,300,301
C   109 IF (X) 302,303,304
C   110 IF (X) 305,306,307
C   111 IF (X) 308,309,310
C   112 IF (X) 311,312,313
C   113 IF (X) 314,315,316
C   114 IF (X) 317,318,319
C   115 IF (X) 320,321,322
C   116 IF (X) 323,324,325
C   117 IF (X) 326,327,328
C   118 IF (X) 329,330,331
C   119 IF (X) 332,333,334
C   120 IF (X) 335,336,337
C   121 IF (X) 338,339,340
C   122 IF (X) 341,342,343
C   123 IF (X) 344,345,346
C   124 IF (X) 347,348,349
C   125 IF (X) 350,351,352
C   126 IF (X) 353,354,355
C   127 IF (X) 356,357,358
C   128 IF (X) 359,360,361
C   129 IF (X) 362,363,364
C   130 IF (X) 365,366,367
C   131 IF (X) 368,369,370
C   132 IF (X) 371,372,373
C   133 IF (X) 374,375,376
C   134 IF (X) 377,378,379
C   135 IF (X) 380,381,382
C   136 IF (X) 383,384,385
C   137 IF (X) 386,387,388
C   138 IF (X) 389,390,391
C   139 IF (X) 392,393,394
C   140 IF (X) 395,396,397
C   141 IF (X) 398,399,400
C   142 IF (X) 401,402,403
C   143 IF (X) 404,405,406
C   144 IF (X) 407,408,409
C   145 IF (X) 410,411,412
C   146 IF (X) 413,414,415
C   147 IF (X) 416,417,418
C   148 IF (X) 419,420,421
C   149 IF (X) 422,423,424
C   150 IF (X) 425,426,427
C   151 IF (X) 428,429,430
C   152 IF (X) 431,432,433
C   153 IF (X) 434,435,436
C   154 IF (X) 437,438,439
C   155 IF (X) 440,441,442
C   156 IF (X) 443,444,445
C   157 IF (X) 446,447,448
C   158 IF (X) 449,450,451
C   159 IF (X) 452,453,454
C   160 IF (X) 455,456,457
C   161 IF (X) 458,459,460
C   162 IF (X) 461,462,463
C   163 IF (X) 464,465,466
C   164 IF (X) 467,468,469
C   165 IF (X) 470,471,472
C   166 IF (X) 473,474,475
C   167 IF (X) 476,477,478
C   168 IF (X) 479,480,481
C   169 IF (X) 482,483,484
C   170 IF (X) 485,486,487
C   171 IF (X) 488,489,490
C   172 IF (X) 491,492,493
C   173 IF (X) 494,495,496
C   174 IF (X) 497,498,499
C   175 IF (X) 500,501,502
C   176 IF (X) 503,504,505
C   177 IF (X) 506,507,508
C   178 IF (X) 509,510,511
C   179 IF (X) 512,513,514
C   180 IF (X) 515,516,517
C   181 IF (X) 518,519,520
C   182 IF (X) 521,522,523
C   183 IF (X) 524,525,526
C   184 IF (X) 527,528,529
C   185 IF (X) 530,531,532
C   186 IF (X) 533,534,535
C   187 IF (X) 536,537,538
C   188 IF (X) 539,540,541
C   189 IF (X) 542,543,544
C   190 IF (X) 545,546,547
C   191 IF (X) 548,549,550
C   192 IF (X) 551,552,553
C   193 IF (X) 554,555,556
C   194 IF (X) 557,558,559
C   195 IF (X) 560,561,562
C   196 IF (X) 563,564,565
C   197 IF (X) 566,567,568
C   198 IF (X) 569,570,571
C   199 IF (X) 572,573,574
C   200 IF (X) 575,576,577
C   201 IF (X) 578,579,580
C   202 IF (X) 581,582,583
C   203 IF (X) 584,585,586
C   204 IF (X) 587,588,589
C   205 IF (X) 590,591,592
C   206 IF (X) 593,594,595
C   207 IF (X) 596,597,598
C   208 IF (X) 599,600,601
C   209 IF (X) 602,603,604
C   210 IF (X) 605,606,607
C   211 IF (X) 608,609,610
C   212 IF (X) 611,612,613
C   213 IF (X) 614,615,616
C   214 IF (X) 617,618,619
C   215 IF (X) 620,621,622
C   216 IF (X) 623,624,625
C   217 IF (X) 626,627,628
C   218 IF (X) 629,630,631
C   219 IF (X) 632,633,634
C   220 IF (X) 635,636,637
C   221 IF (X) 638,639,640
C   222 IF (X) 641,642,643
C   223 IF (X) 644,645,646
C   224 IF (X) 647,648,649
C   225 IF (X) 650,651,652
C   226 IF (X) 653,654,655
C   227 IF (X) 656,657,658
C   228 IF (X) 659,660,661
C   229 IF (X) 662,663,664
C   230 IF (X) 665,666,667
C   231 IF (X) 668,669,670
C   232 IF (X) 671,672,673
C   233 IF (X) 674,675,676
C   234 IF (X) 677,678,679
C   235 IF (X) 680,681,682
C   236 IF (X) 683,684,685
C   237 IF (X) 686,687,688
C   238 IF (X) 689,690,691
C   239 IF (X) 692,693,694
C   240 IF (X) 695,696,697
C   241 IF (X) 698,699,700
C   242 IF (X) 701,702,703
C   243 IF (X) 704,705,706
C   244 IF (X) 707,708,709
C   245 IF (X) 710,711,712
C   246 IF (X) 713,714,715
C   247 IF (X) 716,717,718
C   248 IF (X) 719,720,721
C   249 IF (X) 722,723,724
C   250 IF (X) 725,726,727
C   251 IF (X) 728,729,730
C   252 IF (X) 731,732,733
C   253 IF (X) 734,735,736
C   254 IF (X) 737,738,739
C   255 IF (X) 740,741,742
C   256 IF (X) 743,744,745
C   257 IF (X) 746,747,748
C   258 IF (X) 749,750,751
C   259 IF (X) 752,753,754
C   260 IF (X) 755,756,757
C   261 IF (X) 758,759,760
C   262 IF (X) 761,762,763
C   263 IF (X) 764,765,766
C   264 IF (X) 767,768,769
C   265 IF (X) 770,771,772
C   266 IF (X) 773,774,775
C   267 IF (X) 776,777,778
C   268 IF (X) 779,780,781
C   269 IF (X) 782,783,784
C   270 IF (X) 785,786,787
C   271 IF (X) 788,789,790
C   272 IF (X) 791,792,793
C   273 IF (X) 794,795,796
C   274 IF (X) 797,798,799
C   275 IF (X) 800,801,802
C   276 IF (X) 803,804,805
C   277 IF (X) 806,807,808
C   278 IF (X) 809,810,811
C   279 IF (X) 812,813,814
C   280 IF (X) 815,816,817
C   281 IF (X) 818,819,820
C   282 IF (X) 821,822,823
C   283 IF (X) 824,825,826
C   284 IF (X) 827,828,829
C   285 IF (X) 830,831,832
C   286 IF (X) 833,834,835
C   287 IF (X) 836,837,838
C   288 IF (X) 839,840,841
C   289 IF (X) 842,843,844
C   290 IF (X) 845,846,847
C   291 IF (X) 848,849,850
C   292 IF (X) 851,852,853
C   293 IF (X) 854,855,856
C   294 IF (X) 857,858,859
C   295 IF (X) 860,861,862
C   296 IF (X) 863,864,865
C   297 IF (X) 866,867,868
C   298 IF (X) 869,870,871
C   299 IF (X) 872,873,874
C   300 IF (X) 875,876,877
C   301 IF (X) 878,879,880
C   302 IF (X) 881,882,883
C   303 IF (X) 884,885,886
C   304 IF (X) 887,888,889
C   305 IF (X) 890,891,892
C   306 IF (X) 893,894,895
C   307 IF (X) 896,897,898
C   308 IF (X) 899,900,901
C   309 IF (X) 902,903,904
C   310 IF (X) 905,906,907
C   311 IF (X) 908,909,910
C   312 IF (X) 911,912,913
C   313 IF (X) 914,915,916
C   314 IF (X) 917,918,919
C   315 IF (X) 920,921,922
C   316 IF (X) 923,924,925
C   317 IF (X) 926,927,928
C   318 IF (X) 929,930,931
C   319 IF (X) 932,933,934
C   320 IF (X) 935,936,937
C   321 IF (X) 938,939,940
C   322 IF (X) 941,942,943
C   323 IF (X) 944,945,946
C   324 IF (X) 947,948,949
C   325 IF (X) 950,951,952
C   326 IF (X) 953,954,955
C   327 IF (X) 956,957,958
C   328 IF (X) 959,960,961
C   329 IF (X) 962,963,964
C   330 IF (X) 965,966,967
C   331 IF (X) 968,969,970
C   332 IF (X) 971,972,973
C   333 IF (X) 974,975,976
C   334 IF (X) 977,978,979
C   335 IF (X) 980,981,982
C   336 IF (X) 983,984,985
C   337 IF (X) 986,987,988
C   338 IF (X) 989,990,991
C   339 IF (X) 992,993,994
C   340 IF (X) 995,996,997
C   341 IF (X) 998,999,1000
C   342 IF (X) 1001,1002,1003
C   343 IF (X) 1004,1005,1006
C   344 IF (X) 1007,1008,1009
C   345 IF (X) 1009,1010,1011
C   346 IF (X) 1011,1012,1013
C   347 IF (X) 1014,1015,1016
C   348 IF (X) 1017,1018,1019
C   349 IF (X) 1020,1021,1022
C   350 IF (X) 1023,1024,1025
C   351 IF (X) 1026,1027,1028
C   352 IF (X) 1029,1030,1031
C   353 IF (X) 1032,1033,1034
C   354 IF (X) 1035,1036,1037
C   355 IF (X) 1038,1039,1038
C   356 IF (X) 1040,1041,1042
C   357 IF (X) 1043,1044,1045
C   358 IF (X) 1046,1047,1048
C   359 IF (X) 1049,1050,1051
C   360 IF (X) 1052,1053,1054
C   361 IF (X) 1055,1056,1057
C   362 IF (X) 1058,1059,1058
C   363 IF (X) 1060,1061,1062
C   364 IF (X) 1063,1064,1065
C   365 IF (X) 1066,1067,1068
C   366 IF (X) 1069,1070,1071
C   367 IF (X) 1072,1073,1074
C   368 IF (X) 1075,1076,1077
C   369 IF (X) 1078,1079,1078
C   370 IF (X) 1080,1081,1082
C   371 IF (X) 1083,1084,1085
C   372 IF (X) 1086,1087,1088
C   373 IF (X) 1089,1090,1091
C   374 IF (X) 1092,1093,1094
C   375 IF (X) 1096,1097,1098
C   376 IF (X) 1099,1100,1101
C   377 IF (X) 1102,1103,1104
C   378 IF (X) 1105,1106,1107
C   379 IF (X) 1108,1109,1108
C   380 IF (X) 1110,1111,1112
C   381 IF (X) 1113,1114,1115
C   382 IF (X) 1116,1117,1118
C   383 IF (X) 1119,1119,1119
C   384 IF (X) 1120,1121,1122
C   385 IF (X) 1123,1124,1125
C   386 IF (X) 1126,1127,1128
C   387 IF (X) 1129,1130,1131
C   388 IF (X) 1132,1133,1134
C   389 IF (X) 1135,1136,1137
C   390 IF (X) 1138,1139,1138
C   391 IF (X) 1140,1141,1142
C   392 IF (X) 1143,1144,1145
C   393 IF (X) 1146,1147,1148
C   394 IF (X) 1149,1150,1151
C   395 IF (X) 1152,1153,1154
C   396 IF (X) 1156,1157,1158
C   397 IF (X) 1159,1160,1161
C   398 IF (X) 1162,1163,1164
C   399 IF (X) 1165,1166,1167
C   400 IF (X) 1168,1169,1168
C   401 IF (X) 1170,1171,1172
C   402 IF (X) 1173,1174,1175
C   403 IF (X) 1176,1177,1178
C   404 IF (X) 1179,1180,1181
C   405 IF (X) 1182,1183,1184
C   406 IF (X) 1186,1187,1188
C   407 IF (X) 1189,1190,1191
C   408 IF (X) 1192,1193,1194
C   409 IF (X) 1196,1197,1198
C   410 IF (X) 1199,1200,1201
C   411 IF (X) 1202,1203,1204
C   412 IF (X) 1205,1206,1207
C   413 IF (X) 1208,1209,1208
C   414 IF (X) 1210,1211,1212
C   415 IF (X) 1213,1214,1215
C   416 IF (X) 1216,1217,1218
C   417 IF (X) 1219,1220,1221
C   418 IF (X) 1222,1223,1224
C   419 IF (X) 1226,1227,1228
C   420 IF (X) 1229,1230,1231
C   421 IF (X) 1232,1233,1234
C   422 IF (X) 1235,1236,1237
C   423 IF (X) 1238,1239,1238
C   424 IF (X) 1240,1241,1242
C   425 IF (X) 1243,1244,1245
C   426 IF (X) 1246,1247,1248
C   427 IF (X) 1249,1250,1251
C   428 IF (X) 1252,1253,1254
C   429 IF (X) 1256,1257,1258
C   430 IF (X) 1259,1260,1261
C   431 IF (X) 1262,1263,1264
C   432 IF (X) 1265,1266,1267
C   433 IF (X) 1268,1269,1268
C   434 IF (X) 1270,1271,1272
C   435 IF (X) 1273,1274,1275
C   436 IF (X) 1276,1277,1278
C   437 IF (X) 1279,1280,1281
C   438 IF (X) 1282,1283,1284
C   439 IF (X) 1286,1287,1288
C   440 IF (X) 1289,1290,1291
C   441 IF (X) 1292,1293,1294
C   442 IF (X) 1296,1297,1298
C   443 IF (X) 1299,1300,1301
C   444 IF (X) 1302,1303,1304
C   445 IF (X) 1305,1306,1307
C   446 IF (X) 1308,1309,1308
C   447 IF (X) 1310,1311,1312
C   448 IF (X) 1313,1314,1315
C   449 IF (X) 1316,1317,1318
C   450 IF (X) 1319,1320,1321
C   451 IF (X) 1322,1323,1324
C   452 IF (X) 1325,1326,1327
C   453 IF (X) 1328,1329,1328
C   454 IF (X) 1330,1331,1332
C   455 IF (X) 1333,1334,1335
C   456 IF (X) 1336,1337,1338
C   457 IF (X) 1339,1340,1341
C   458 IF (X) 1342,1343,1344
C   459 IF (X) 1346,1347,1348
C   460 IF (X) 1349,1350,1351
C   461 IF (X) 1352,1353,1354
C   462 IF (X) 1356,1357,1358
C   463 IF (X) 1359,1360,1361
C   464 IF (X) 1362,1363,1364
C   465 IF (X) 1365,1366,1367
C   466 IF (X) 1368,1369,1368
C   467 IF (X) 1370,1371,1372
C   468 IF (X) 1373,1374,1375
C   469 IF (X) 1376,1377,1378
C   470 IF (X) 1379,1380,1381
C   471 IF (X) 1382,1383,1384
C   472 IF (X) 1386,1387,1388
C   473 IF (X) 1389,1390,1391
C   474 IF (X) 1392,1393,1394
C   475 IF (X) 1396,1397,1398
C   476 IF (X) 1399,1400,1401
C   477 IF (X) 1402,1403,1404
C   478 IF (X) 1405,1406,1407
C   479 IF (X) 1408,1409,1408
C   480 IF (X) 1410,1411,1412
C   481 IF (X) 1413,1414,1415
C   482 IF (X) 1416,1417,1418
C   483 IF (X) 1419,1420,1421
C   484 IF (X) 1422,1423,1424
C   485 IF (X) 1426,1427,1428
C   486 IF (X) 1429,1430,1431
C   487 IF (X) 1432,1433,1434
C   488 IF (X) 1435,1436,1437
C   489 IF (X) 1438,1439,1438
C   490 IF (X) 1440,1441,1442
C   491 IF (X) 1443,1444,1445
C   492 IF (X) 1446,1447,1448
C   493 IF (X) 1449,1450,1451
C   494 IF (X) 1452,1453,1454
C   495 IF (X) 1456,1457,1458
C   496 IF (X) 1459,1460,1461
C   497 IF (X) 1462,1463,1464
C   498 IF (X) 1465,1466,1467
C   499 IF (X) 1468,1469,1468
C   500 IF (X) 1470,1471,1472
C   501 IF (X) 1473,1474,1475
C   502 IF (X) 1476,1477,1478
C   503 IF (X) 1479,1480,1481
C   504 IF (X) 1482,1483,1484
C   505 IF (X) 1486,1487,1488
C   506 IF (X) 1489,1490,1491
C   507 IF (X) 1492,1493,1494
C   508 IF (X) 1496,1497,1498
C   509 IF (X) 1499,1500,1501
C   510 IF (X) 1502,1503,1504
C   511 IF (X) 1505,1506,1507
C   512 IF (X) 1508,1509,1508
C   513 IF (X) 1510,1511,1512
C   514 IF (X) 1513,1514,1515
C   515 IF (X) 1516,1517,1518
C   516 IF (X) 1519,1520,1521
C   517 IF (X) 1522,1523,1524
C   518 IF (X) 1526,1527,1528
C   519 IF (X) 1529,1530,1531
C   520 IF (X) 1532,1533,1534
C   521 IF (X) 1535,1536,1537
C   522 IF (X) 1538,1539,1538
C   523 IF (X) 1540,1541,154
```

```

15 ROOT=0,0
15 RETURN;
14 Y5=Y
14 DC 33 LB=1,13
6C T3 {21,22,23,24,25,26,27,28,29,30},<
24 P=X
6C TC 31
22 F=(Y*X)/(2.0*Y)
6C TC 31
23 Y2=Y*Y
23 P=(2.0*Y2*X)/(3.0*Y2)
6C TC 31
24 Y2=Y*Y
24 Y4=Y2*Y2
F=(3.0*Y4*X)/(4.0*Y2*Y)
6C TC 31
25 Y2=Y*Y
25 Y4=Y2*Y2

```

C

# ONE DIMENSIONAL GAS PARTICLE FLOW

```

P=(4.0*Y4+X)/(5.0*Y4)
GO TO 31
26 Y2=Y*Y
    Y4=Y2*Y2
    P=(5.0*Y4+Y2+X)/(6.0*Y4+Y)
    GO TO 31
27 Y2=Y*Y
    Y4=Y2*Y2
    Y6=Y4*Y2
    P=(6.0*Y6+Y+X)/(7.0*Y6+Y)
    GO TO 31
28 Y2=Y*Y
    Y4=Y2*Y2
    P=(7.0*Y4+Y4+X)/(5.0*Y4+Y2+Y)
    GO TO 31
29 Y2=Y*Y
    Y4=Y2*Y2
    Y8=Y4*Y4
    P=(8.0*Y8+Y+X)/(9.0*Y8+Y)
    GO TO 31
30 Y2=Y*Y
    Y4=Y2*Y2
    Y8=Y4*Y4
    P=(9.0*Y8+Y2+X)/(10.0*Y8+Y)
    IF (ABS(1.0-Y/P)-1.0E-5)34,34,32
32 Y=P
33 CC:TIME
34 FACT=P
      RETURN
END

```

**APPENDIX B**  
**TWO-DIMENSIONAL GAS PARTICLE FLOW**

TWO-DIMENSIONAL GAS PARTICLE FLOW

```
READ (11) K1, T1(LL), PINC(LL), CIND(LL), WINDG(LL), WINOP(LL);
2 FMV(LL)
1F (K1-G42) 37,28,36
37 CONTINUE
38 CONTINUE
39 CONTINUE
REWIND 14
DO 39 LLL=2,L5
      WINDG(LL)=WINDP(LL)
      WINDP(LL)=WIND(LL)
      T1(1)=0.
      PINC(LL)=0.
      CIND(LL)=0.
      WINDG(1)=0.
      WINDP(1)=0.
      WIND(1)=0.
      READ (5,1020) N1,N2,(N3(I,J),I=1,4),J=1,8)
1020 FORMAT (112/8110,112/8110)
```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

KK = -1
KK0=-1
IM=11+IP-1
IT = 11+2
IS = 11+1
IA = 11-2
I2 = 11-1
JA = 11-2
JB = 11-1
READ (5,11) RMAX,ZMAX,ZREF
1102 FORMAT (3E14.5)
WHITE (5,2,0),RMAX,ZMAX,ZREF,14.5,ZMAX,E14.5,ZREF,E14.5)
2002 FORMAT (1H,5X,BMAX,X,2,0,0,RQ,JD,
CALL U-EQR (JW,RMAX,2,0,0,RQ,JD,
IM1,ZMAX,1,IP)
CALL U-EQR (IM1,ZMAX,2,ZREF,ZPN,1D)
20 2(1)=ZPN(11)-ZPN(11+1)
20 2(2)=ZS(11)
20 2(3)=2FN(11)+ZPN(11+1)
20 2(4)=J2,JB
14 R(J+1)=0.5*(RR(J)+RR(J+1))
F(2)=-P(2)
DO 22 I = 1,5*(Z1+1)+Z(1)
22 Z(1) = 1.5*(Z1+1)+Z(1)
DO 24 I = 2,2*(11)-2*(1-1)
24 DEL2(I) = 1.2*(11)-2*(1-1)
DO 25 I = 2,2*(11)-2*(1-1)
25 DEL2(I) = Z(2)(11)*Z22(I-1)
DO 26 I = 2,2*(11)-2*(1-1)
26 DEL2(I) = Z(2)(11)*Z22(I-1)
22 DEL2(I) = Z(2)(11)-R(J,P1)
DO 27 I = 2,2*(11)-2*(1-1)
27 DEL2(I) = HQ(I)*RR(I-1)
DE1(I) = 3.42*(R3(I)*Z(1)*RR(I-1))
A2(I) = 3.42*(R3(I)*Z(1)*RR(I-1))
42(I) = 3.42*(R3(I)*Z(1)*RR(I-1))
4Z(I) = 3.42*(R3(I)*Z(1)*RR(I-1))
DO 28 I = 1,18
DO 29 I = 1,JB
AR(I) = 5.283*ZRA(J)*DELZZ(I)
AR(I+1) = 6.283*ZRA(J)*DELZ(I+1)
MAIN0580
MAIN0590
MAIN0600
MAIN0610
MAIN0620
MAIN0630
MAIN0640
MAIN0650
MAIN0660
MAIN0670
MAIN0680
MAIN0690
MAIN0700
MAIN0710
MAIN0720
MAIN0730
MAIN0740
MAIN0750
MAIN0760
MAIN0770
MAIN0780
MAIN0790
MAIN0800
MAIN0810
MAIN0820
MAIN0830
MAIN0840
MAIN0850
MAIN0860
MAIN0870
MAIN0880
MAIN0890
MAIN0900
MAIN0910
MAIN0920
MAIN0930
MAIN0940
MAIN0950
MAIN0960
MAIN0970
MAIN0980
MAIN0990
MAIN0991
MAIN0992
MAIN0993
MAIN0994
MAIN0995
MAIN0996
MAIN0997
MAIN0998
MAIN0999
MAIN0999

```

26 APR(1,0,J) = 0.2H30H(J)\*TELZZ(1)  
 03 26 !=2,14  
 00 26 JS2,14  
 V2,1,J; = 4,(J-1)\*TELZZ(1)  
 V2,1,J; = 4,(J-1)\*TELZZ(1+1)  
 26 V2,1,J; = 4,(J-1)\*TELZZ(1+1)  
 26 FOR I=1,6,202,I,14,J,KM,4ST,KKST  
 13CX3+2-P455/2-2 AXIAL SYMMETRY FLOW MODEL //  
 245X4+1,216545X4H,14,16/45X4HJM 3=16/45X4HJM 3,16/  
 3 45X,4,4ST,160 / 45X,5,4ST,14 / 1X/  
 VATE(16,2104) =3.04T\*DATA,F,J,RRDP,CIA,P,VFLMAX,PAVIFL,ER  
 2704 EOP147 (14),  
 1.9X3C,1.02Z2.5 RAD115,RC  
 223X3C,AT,035-E HIC PRESSURE,DATA  
 323X3,DATA,0SP-E HIC TENSIT,DATA  
 423X3,MECHANICAL-HEAT EQUIV.,F,J  
 523X3,PARTICULATE DENSIT,VERHOP  
 MAIN0970  
 MAIN0980  
 MAIN0990  
 MAIN1000  
 MAIN1010  
 MAIN1020  
 MAIN1030  
 MAIN1040  
 MAIN1050  
 MAIN1060  
 MAIN1070  
 MAIN1080  
 MAIN1090  
 MAIN1100  
 MAIN1110  
 MAIN1120  
 MAIN1130  
 MAIN1140

THE THREE-DIMENSIONAL GAS PARTICLE FLUX

B-7

TWO DIMENSIONAL GAS PARTICLE FLOW

```

      RE(L) = REF(M)
      AE(L) = RE(M)*AEF(M)
      62 Y(L) = F(I,J,N)
      60 CONTINUE
      IARK = L
      T = 0.
      DT = .0001
      EXTERNAL DERIVICNTL
      REWIND 9
      REWIND 9
      REWIND 10
      IF (KST=2) 34,30,34
      30 DO 31 K=1,10000
      READ (K,T,D,T,(Y(I)),(Z(I)),(RK))
      READ (10) K1
      IF (KK"KKS!) 31,32,32
      31 CONTINUE
      32 CONTINUE
      DO 41 LL=1,10000
      READ (8) K<1
      IF (KK"KK) 41,42,42
      41 CONTINUE
      42 CONTINUE
      KK"KK"1
      34 CONTINUE (DERIVICNTL,Y,D,Y,AE,RE,I,T,D,T,I,RK,.2,0E6)
      CALL RK2
      REWIND 8
      REWIND 9
      REWIND 10
      STOP
      END

```

TWO DIMENSIONAL GAS PARTICLE FLOW

SUBROUTINE DERIV(Y,OY,T)  
CELL AND DEFINITION OF ASSOCIATED VARIABLES

(I,J+1)\*

DERI0010  
DERI0020  
DERI0030  
\* DERI0040  
DERI0050  
DERI0060  
DERI0070  
DERI0080  
DERI0090  
DERI0100  
DERI0110  
DERI0120  
DERI0130  
DERI0140  
DERI0150  
DERI0160  
DERI0170  
DERI0180  
DERI0190  
DERI0200  
DERI0210  
DERI0220  
DERI0230  
DERI0240  
DERI0250  
DERI0260  
DERI0270  
DERI0280  
DERI0290  
DERI0300  
DERI0310  
DERI0320  
DERI0330  
DERI0340  
DERI0350  
DERI0360  
DERI0370  
DERI0380  
DERI0390

F(I,J,2)

F(I,J,5)

G2(I,J,4)

G2(I,J,7)

U

C(N,E,P)

F(I,J,1)

F(I,J,4)

F(I,J,7)

(I,J) \*

G2(I,J,3)

G2(I,J,6)

G2(I,J,2)

G2(I,J,5)

F(I,J,3)

F(I,J,6)

G2(I,J,1)

G2(I,J,4)

G2(I,J,7)

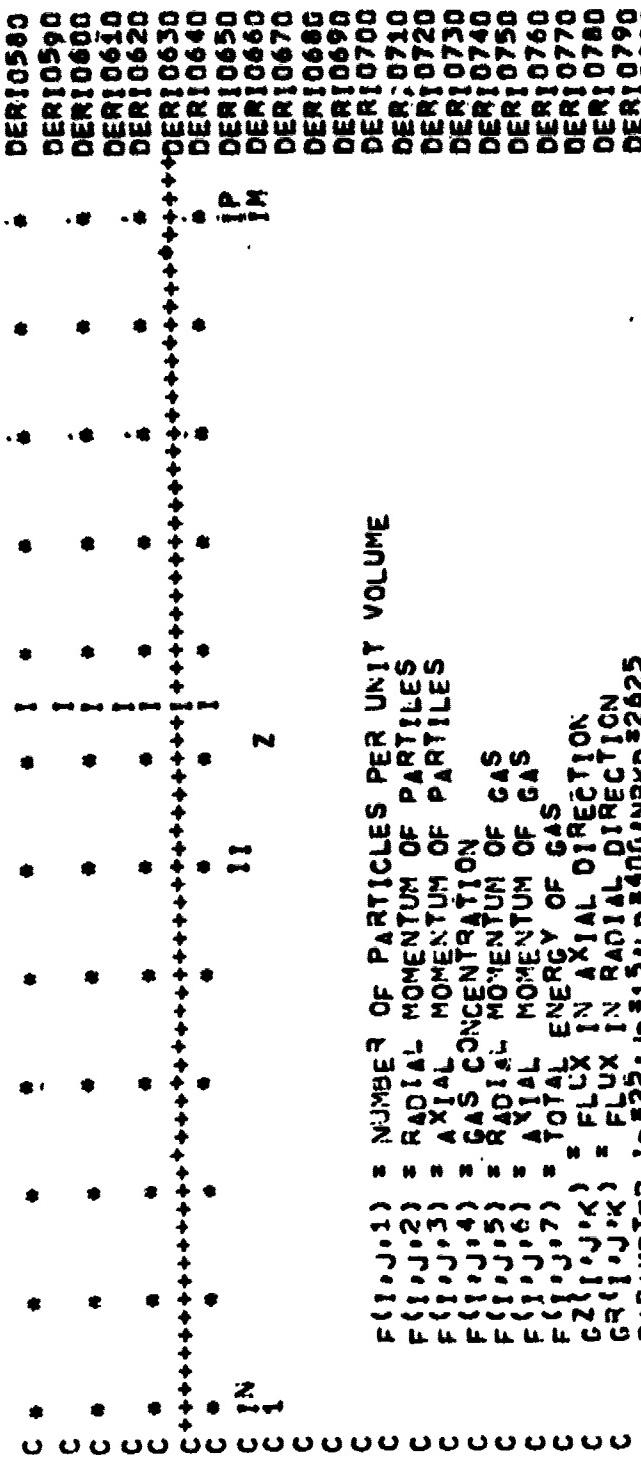
D(I,J)

(I,J)

BARREL AND DISTRIBUTION OF NODES

B-10

TWO DIMENSIONAL GAS PARTICLE FLOW



F(I,J,1) = NUMBER OF PARTICLES PER UNIT VOLUME

F(I,J,2) = RADIAL MOMENTUM OF PARTICLES

F(I,J,3) = AXIAL MOMENTUM OF PARTICLES

F(I,J,4) = GAS CONCENTRATION

F(I,J,5) = RADIAL MOMENTUM OF GAS

F(I,J,6) = AXIAL MOMENTUM OF GAS

F(I,J,7) = TOTAL ENERGY OF GAS

F2(I,J) = FLUX IN AXIAL DIRECTION

G(I,J) = FLUX IN RADIAL DIRECTION

PARAMETER I(NRKD)=25, J(NRKD)=400, NAKD=2625

DIMENSION /L/, /R/, /Z/, /P/, /Q/, /R/, /J/, /D/

CWAVEON /AL/, /FL/, /UR/, /PA/, /EL/, /RC/, /K/, /KK/, /OK/, /PK/, /RN/, /RHO/, /T/

1F4 /VOLP/, /APF/, /VELMA/, /PAV/, /ELG/, /KU/, /KKU/, /OKU/, /PKU/, /RN/, /RHO/, /T/

2A1 /L1/, /R1/, /Z1/, /P1/, /Q1/, /R1/, /J1/, /D1/, /IND1/, /N1/, /RD1/, /T1/

3Z1 /L2/, /R2/, /Z2/, /P2/, /Q2/, /R2/, /J2/, /D2/, /IND2/, /N2/, /RD2/, /T2/

4Z2 /L3/, /R3/, /Z3/, /P3/, /Q3/, /R3/, /J3/, /D3/, /IND3/, /N3/, /RD3/, /T3/

5VR /L4/, /R4/, /Z4/, /P4/, /Q4/, /R4/, /J4/, /D4/, /IND4/, /N4/, /RD4/, /T4/

6VY /L5/, /R5/, /Z5/, /P5/, /Q5/, /R5/, /J5/, /D5/, /IND5/, /N5/, /RD5/, /T5/

7WPR /L6/, /R6/, /Z6/, /P6/, /Q6/, /R6/, /J6/, /D6/, /IND6/, /N6/, /RD6/, /T6/

8EW /L7/, /R7/, /Z7/, /P7/, /Q7/, /R7/, /J7/, /D7/, /IND7/, /N7/, /RD7/, /T7/

9GNY /L8/, /R8/, /Z8/, /P8/, /Q8/, /R8/, /J8/, /D8/, /IND8/, /N8/, /RD8/, /T8/

10GRU /L9/, /R9/, /Z9/, /P9/, /Q9/, /R9/, /J9/, /D9/, /IND9/, /N9/, /RD9/, /T9/

11DATA /SS/30000/, /REAL N1/N2/N3/N4/N5/N6/N7/N8/N9/N10/

12COMMON /OC/, /CN/, /HNG/, /INP/, /INR/, /GRM/, /ID/, /GZM/, /ID/, /JD/

13HNG /NP/, /DR/, /ID/, /JD/, /INP/, /INR/, /GRM/, /ID/, /GZM/, /ID/, /JD/

14INP /ID/, /JD/, /INR/, /GRM/, /ID/, /GZM/, /ID/, /JD/

15GRM /ID/, /JD/, /INR/, /GRM/, /ID/, /GZM/, /ID/, /JD/

16ID /ID/, /JD/, /INR/, /GRM/, /ID/, /GZM/, /ID/, /JD/

17JD /ID/, /JD/, /INR/, /GRM/, /ID/, /GZM/, /ID/, /JD/

C CONVERT F(I,J,N) FROM Y(L)

```
L=0  
DO 1 I=2,1A  
C0 1 J=2,J4  
IF(J.EQ.2.AND.I.LT.IS) GO TO 1  
DO 3 M=1,7  
L=L+1  
3 F(I,J,M)=Y(L)  
1 CONTINUE
```

C CONVERT PHYSICAL VARIABLES FROM F(I,J,N) : EXCEPT CRUG AND CZWG

```
DO 10 I=2,1A  
DO 10 J=2,JA  
IF(J.EQ.2.AND.I.LT.IS) GO TO 15  
N(I,J)=F(I,J,1)  
N(I,J)=F(I,J,2)  
UP(I,J)=F(I,J,2)  
WP(I,J)=F(I,J,3)  
C(I,J)=F(I,J,4)  
E(I,J)=F(I,J,7)
```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

50 CONTINUE
C BOUNDARY VALUES FOR C(I,J)
C(I8,2)=C(1A,2)
DO 12 J=3,JA
C(I8,J)=C(1A,J)
12 C(I1,J)=C(2,J)
DO 24 I=1,IB
C(I1,I)=C(1,I)
24 C(I,J)=C(2,J)
DO 26 I=1,IS
C CONVERT UG AND VG FROM FT(I,J,M)
DO 24 I=2,IA
IF(I-EQ.2.EQ.0.LT.IS) GO TO 24
C2(I,J)=5*(C1(I+1,J)+C1(I,J))
C8(I,J)=5*(C1(I,J)+C1(I,J-1))
UG(I,J)=(C1(I,J)+C8(I,J))/2
VG(I,J)=(C1(I,J)+C2(I,J))/2
DO 30 J=3,JA
C SET BOUNDARY VALUES FOR PHYSICAL VARIABLES
DO 30 J=3,JA
E(I,J)=E(1A,J)
E(1B,J)=E(1A,J)
UP(1,J)=UP(2,J)
UP(2,J)=UP(1,J)
UG(1,J)=UG(2,J)
UG(2,J)=UG(1,J)
DP(1,J)=DP(2,J)
DP(2,J)=DP(1,J)
NP(1,J)=NP(2,J)
NP(2,J)=NP(1,J)
UP(1,J)=UP(2,J)
UP(2,J)=UP(1,J)
UG(1,J)=UG(2,J)
UG(2,J)=UG(1,J)
DP(1,J)=DP(2,J)
DP(2,J)=DP(1,J)
NP(1,J)=NP(2,J)
NP(2,J)=NP(1,J)
E(I,J)=E(1A,J)
E(1B,J)=E(1A,J)
UP(1,J)=UP(2,J)
UP(2,J)=UP(1,J)
UG(1,J)=UG(2,J)
UG(2,J)=UG(1,J)
DP(1,J)=DP(2,J)
DP(2,J)=DP(1,J)
NP(1,J)=NP(2,J)
NP(2,J)=NP(1,J)
DERI1150
DERI1160
DERI1170
DERI1180
DERI1190
DERI1200
DERI1210
DERI1220
DERI1230
DERI1240
DERI1250
DERI1260
DERI1270
DERI1280
DERI1290
DERI1300
DERI1310
DERI1320
DERI1330
DERI1340
DERI1350
DERI1360
DERI1370
DERI1380
DERI1390
DERI1400
DERI1410
DERI1420
DERI1430
DERI1440
DERI1450
DERI1460
DERI1470
DERI1480
DERI1490
DERI1500
DERI1510
DERI1520
DERI1530

```

N(1,JB)=N(1,JA)  
UP(1,JB)=U<sup>2</sup>(1,JA)  
UG(1,JB)=U<sup>3</sup>(1,JA)  
XP(1,JB)=U<sup>4</sup>(1,JA)  
WG(1,JB)=U<sup>5</sup>(1,JA)  
DO(36,1)=2011  
E(1,2)=E(1,3)  
N(1,2)=N(1,3)  
KP(1,2)=KP(1,3)  
KG(1,2)=KG(1,3)  
UP(1,2)=0  
UG(1,2)=0  
DO(36,1)=15118  
E(1,1)=E(1,2)  
N(1,1)=N(1,2)  
KP(1,1)=KP(1,2)  
KG(1,1)=KG(1,2)  
IG(1,1)=0

34 DERI1540  
DERI1550  
DERI1560  
DERI1570  
DERI1580  
DERI1590  
DERI1600  
DERI1610  
DERI1620  
DERI1630  
DERI1640  
DERI1650  
DERI1660  
DERI1670  
DERI1680  
DERI1690  
DERI1700  
DERI1710

TWO-DIMENSIONAL GAS PARTICLE FLOW



TWO DIMENSIONAL GAS PARTICLE FLOW

C INTERIOR REGION CALCULATIONS FOR COMPUTED VARIABLES

DO 40 I=2,4

DO 40 J=2,4

IF(I-J-2,2,AND,I-J,1) GO TO 45

E1(I,J)=E(I,J)/C(I,J)\*2+K(I,J)\*\*2+UG(I,J)\*\*2+UG(I,J-1)\*\*2/F

2\*0.25\*(VFL(I,J)\*VFL(I,J-1)

VFL=LN(1.0-VFL)\*9999

VFL=MAX(VFL,0.0)

PD(I,J)=C(I,J)\*VFL

PD(I,J)=C(I,J)\*VFL

IF(VFL>GE,VFL=MAX(PD(I,J),PD(I,J-1))

PL=I-J-4

RHO=C(I,J)\*VFL

DEL=K(I,J)\*C(I,J)\*VFL

DER12300  
DER12310  
DER12320  
DER12330  
DER12340  
DER12350  
DER12360  
DER12370  
DER12380  
DER12390  
DER12400  
DER12410  
DER12420  
DER12430  
DER12440  
DER12450  
DER12460  
DER12470  
DER12480  
DER12490  
DER12500  
DER12510  
DER12520  
DER12530  
DER12540  
DER12550  
DER12560  
DER12570  
DER12580  
DER12590  
DER12600  
DER12610  
DER12620  
DER12630  
DER12640  
DER12650  
DER12660  
DER12670

```

DFP = "APPENDEN.VFS
ANGATAN(DJD/DWD)
DZ(J,J) = CDF * COS(ANG)
DR(J,J) = SIN(ANG)

40 CONTINUE
KUG(J,J) = 0
IF (JPI(J,J) .GT. 0) KUG(J,J) = 0
IF (JUP(J,J) .GT. 0) KUP(J,J) = 0
IF (JCL(J,J) .GT. 0) LWC(J,J) = 0
IF (JCL(J,J) .LT. 0) KUG(J,J) = 0
DO 50 J=3,J1
P(1,J) = P(2,J)
C(1,J) = CD(2,J)
C(2,J) = 32(2,J)

```

```

DERI2680 DERI2690
DERI2700 DERI2710
DERI2720 DERI2730
DERI2740 DERI2750
DERI2760 DERI2770
DERI2780 DERI2790
DERI2800 DERI2810
DERI2820 DERI2830
DERI2840 DERI2850

```

C SET BOUNDARY VALUES FOR COMPUTED VARIABLES

TWO DIMENSIONAL GAS PARTICLE FLOW

D2(1,J)=D2(2,J)

LUP(1,J) = LUP(2,J)

LUG(1,J) = LUG(2,J)

UCD(1,J) = UCD(2,J)

WCD(1,J)=WCD(2,J)

Q0 52 J=2,4

P(1,B,J)=P(1,A,J)

GZ(1,B,J) = GZ(1,A,J)

PD(1,B,J)=PD(1,A,J)

WCN(1,B,J)=WCN(1,A,J)

Q0 54 I=2,1A

P(1,B,J)=P(1,A,J)

GR(1,B,J)=GR(1,A,J)

UCN(1,B,J)=UCN(1,A,J)

Q0 56 I=2,1B

P(1,B,J)=P(1,A,J)

GR(1,B,J)=GR(1,A,J)

CD(1,B,J)=CD(1,A,J)

DR(1,B,J)=DR(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

KUP(1,B,J)=KUP(1,A,J)

KUG(1,B,J)=KUG(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

DR(1,B,J)=DR(1,A,J)

KUP(1,B,J)=KUP(1,A,J)

KUG(1,B,J)=KUG(1,A,J)

GR(1,B,J)=GR(1,A,J)

CD(1,B,J)=CD(1,A,J)

DR(1,B,J)=DR(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

KUP(1,B,J)=KUP(1,A,J)

KUG(1,B,J)=KUG(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

DR(1,B,J)=DR(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

DR(1,B,J)=DR(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

DR(1,B,J)=DR(1,A,J)

WCD(1,B,J)=WCD(1,A,J)

DR(1,B,J)=DR(1,A,J)

DERI 2860  
 DERI 2870  
 DERI 2880  
 DERI 2890  
 DERI 2900  
 DERI 2910  
 DERI 2920  
 DERI 2930  
 DERI 2940  
 DERI 2950  
 DERI 2960  
 DERI 2970  
 DERI 2980  
 DERI 2990  
 DERI 3000  
 DERI 3010  
 DERI 3020  
 DERI 3030  
 DERI 3040  
 DERI 3050  
 DERI 3060  
 DERI 3070  
 DERI 3080  
 DERI 3090  
 DERI 3100  
 DERI 3110  
 DERI 3120  
 DERI 3130  
 DERI 3140  
 DERI 3150  
 DERI 3160  
 DERI 3170  
 DERI 3180  
 DERI 3190  
 DERI 3200  
 DERI 3210  
 DERI 3220  
 DERI 3230  
 DERI 3240

CALCULATE GAS MOMENTUM FLUXES

DO 500 J=1,M

DO 300 J=1,M

```

IM1=MAX0(I-1,1)
WGB=0.5*(W3(IM1,J)+WG(1,J))
CALL LOFU(4GB,L)
IM1PL=MIN0(I-1,L,IM1)
IM2PL=MIAZO(IM1PL,I)
GZW(I,J)=A2(J)*C(I,J)*(WG(IM1PL,J)**2)
IP1=MIN0(I+1,L,N)
UCB=0.5*(UJ(I,J)+UG(IP1,J))
CALL LOFU(JCB,K)
JPK=MIN0(J-K,J)
JP1=MIN0(J+1,J)
CA=C(I,J)+C(IP1,J)+C(I,JP1)+C(IP1,JPK)
GRW(I,J)=A3(I,J)*CA*UGB*WG(I,JPK)
JY1=34AX0(J-1,1)
UCB=0.5*(UJ(I,JM1)+UG(I,J))
CALL LOFU(JCB,K)
JM1PK=MIAZO(JM1PK,I)
JM2PK=MIAZO(JM2PK,I)

```

O O

TWO DIMENSIONAL GAS PARTICLE FLOW

```

CRU(I,J)=A2*V(I,J)*C(I,J)*(UG(I,J)*PK)+0.2)
VG=0.5*(UG(I,J)+UG(I+1,J))
CALL LOFU(45B,L)
VPL=MIN(I+1,J)
GZJ(I,J)=AZJ(I,J)*CB*WGB*UG(IPL,J)
C COMPUTE DF((IS,2,M) AT NOZZLE CELL
C
LP = LNP((IS,2))
KP = KNP((IS,2))
NFI((IS,2,1) = (AZ((2)*(WINP*VN-NP((IS,2)*VN*(S+LP,2)))
1 -AH((IS,2)*UP((IS,2)*VN((IS,2+KP)))/VN((IS,2))
C
TERM1 = -U^2((IS,2))/DELZ((IS))
IF (UPR((IS,2),LT,0,)) TERM1 = (UP((IS,2))-UP((IS,2))/DELZ((IS))
DF((IS,2,2) = WPR((IS,2))*TERM1+UP((IS,2)*(UP((IS,2+KP))-UP((IS,1+KP))/-
DELR((2+KP,3)*DR((IS,2)/48)*(PD((IS,3)-P((IS,2))/VN((S,2)*VN*DELR(3)),
2*GP((IS,3)*GPR((IS,2))/VN*NR((IS,2))/DEL((3))
DELR(3)
DELR(3560
DELR(3570
DELR(3580
DELR(3590
DELR(3600
DELR(3610
DELR(3620
DELR(3630
DELR(3640
DELR(3650
DELR(3660
DELR(3670
DELR(3680
DELR(3690
DELR(3700
DELR(3710
DELR(3720
DELR(3730
DELR(3740
DELR(3750
DELR(3760
DELR(3770
DELR(3780
DELR(3790
DELR(3800
DELR(3810
C
TERM1 = (WINP-WP((IS,2))/DELZ((IS))
IF (WP((IS,2),LT,0,)) TERM1 = (WP((IS,2))-WP((IS,2))/DELZ((IS))
TERM1 = (WP((IS,2))/DELZ((IS))
IF (UPZ((IS,2),LT,0,)) TERM2 = (WP((IS,3))-WP((IS,2))/DEL((3))
C
DF((IS,2,3) = WP((IS,2))*TERM1-UPZ((IS,2)*TERM2-DZ((IS,2)/VN*DELR(3)
1-(PD((IT,2)-PD((IS,2))/48*(IS,2)/48*DELZ((IT))
2-(GP((IT,2)-GP((IS,2))/48*(IS,2)/48*DEL((IT))
C
LP = LNC((IS,2))
KP = KNG((IS,2))
CF((IS,2,4) = (AZ((2)*(WINP*CN-VG((IS,2)*C((S+LP,2))-/
AR((IS,2)*UG((IS,2)*C((IS,2+KP)))/VN((IS,2))
2*AR((IS,2)*(P((IS,3)+GR((IS,3)*P((IS,2)*GR((IS,2)))/VN((IS,2))
3*VR((IS,2)*C2((IS,2))
C

```

```

WB=0.5*(WN3+WG(1S,2))
IF (WB) 302,301,301
301 WBB*WN3
GO TO 303
302 WBB*WG(1S,2)
303 GZM1=AZ(2)*C(1S,2)*(WBB**2)
DF(1S,2,6)=GZM1=GZW(1S+1,2)*GW(1S,2)
2-AZ(2)*(P(1T,2)+GZ(1T,2)-P(1S,2)+GZ(1S,2))/VZ(1S,2)
3+NZ(1S,2)*DZ(1S,2)
C DF(1S,2,7) = ((AZ(2)*(1NG*(E1N*FJ+PLN)-WG(1S,2)*(E(1S+LP,2)*FJ+
IN(1S+LP,2)*GZ(1S+LP,2))-A(1S,2)*UG(1S,2)*E(1S,2+KP)*FJ+
2P(1S,2+KP)+3R(1S,2+KP))/V(1S,2)+.5*N(1S,2)*DZ(1S,2)*WF(1S,2)+3QR(1S,2)*U(1S,2))/FJ
C CALCULATE DF VALUES AT INTERIOR NODES
C 00 200 1*2,14

```

TWO DIMENSIONAL GAS PARTICLE FLOW

DERI4000  
DERI4020  
DERI4030  
DERI4040  
DERI4050  
DERI4060  
DERI4070  
DERI4080  
DERI4090  
DERI4100  
DERI4110  
DERI4120  
DERI4130  
DERI4140  
DERI4150  
DERI4160  
DERI4170  
DERI4190  
DERI4200  
DERI4210  
DERI4220  
DERI4230  
DERI4240  
DERI4250  
DERI4260  
DERI4270  
DERI4280  
DERI4300  
DERI4320  
DERI4330  
DERI4350  
DERI4360  
DERI4370  
DERI4380  
DERI4390  
DERI4400  
DERI4410  
DERI4420  
DERI4430  
DERI4440  
DERI4450  
DERI4460  
DERI4470  
DERI4480  
DERI4490  
DERI4500  
DERI4510  
DERI4520  
DERI4530  
DERI4540  
DERI4550  
DERI4560  
DERI4570  
DERI4580  
DERI4590  
DERI4600  
DERI4610  
DERI4620  
DERI4630  
DERI4640  
DERI4650  
DERI4660  
DERI4670  
DERI4680  
DERI4690  
DERI4700  
DERI4710  
DERI4720  
DERI4730  
DERI4740  
DERI4750  
DERI4760  
DERI4770  
DERI4780  
DERI4790  
DERI4800  
DERI4810  
DERI4820  
DERI4830  
DERI4840  
DERI4850  
DERI4860  
DERI4870  
DERI4880  
DERI4890  
DERI4900  
DERI4910  
DERI4920  
DERI4930  
DERI4940  
DERI4950  
DERI4960  
DERI4970  
DERI4980  
DERI4990  
DERI5000

```

C
DF(I,J,J) = ((AZ(J)*WG(I,J))*E(I-J+LN,J)*FJ*P(I-LN,J))*
1GZ(I-J+LN,J)*((E(I+P,J)*FU+(I+LP,J)*GZ(I+LP,J)))*
24R(I-J)*UG(I,J)*((E(I-J+KP)*FJ+P(I-J+KP)+GR(I-J+KP)))*
3UG(I-J-1)*((E(I-J+KN)*FJ+P(I-J+KN)+GR(I-J+KN)))*Y(I-J+)
4.G+N(I,J)*UZ(I,J)*WP(I,J)+D2(I-J)*WP(I-J)*GR(I-J)*UP(I-J)*
5DR(I,J-1)*JP(I,J-1))/FJ
DERI4390
DERI4400
DERI4420
DERI4430
DERI4440
DERI4450
DERI4460
DERI4470
DERI4480
DERI4490
DERI4500
DERI4510
DERI4520
DERI4530
DERI4540
DERI4550
DERI4560
DERI4570

200 CONTINUE DYL FROM DF(I,J,M)
L=0
DO 2 I=2,12
DO 2 J=2,12
IF (J.EQ.2,AND,I.EQ.1,IS) GO TO 2
DO 4 H=1,7
L=L+1
4 DYL(L)=DF(I,J,H)
2 CONTINUE
RETURN
END

```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE CNTRL(Y,DY,DT,T,NTRY)
PARAMETER IC=25,JD=15,LD=400,NAKD=2625
DIMENSION Y(NRKD),G(NRKD)
COMMON /DC/ C1,C2,C3,C4,WNP,NV,
           GRU(ID,JD),GRW(ID,JD),GZW(ID,JD),
           COMMON /AL-/ ,F(ID,JD,7),DF(ID,JD,7),
           1F,J,VOLP,NM,APF,V=LNAX,PAV,FLRS,KWKK,KK0,KH,PIN,IRK,RHOP,
           2,TT(LD),PING(LD),CIND(LD),NIND(LD),
           3Z(ID),Z2(ID),DELZ(ID),RR(JD),DELR(JD),DELRR(JD),
           4A2(JD),AZC(JD),ARZ(ID,JD),ARV(ID,JD),ARD(ID,JD),
           SVR(ID,JD),C(ID,JD),CR(ID,JD),CD(ID,JD),WG(ID,JD),
           6xGN(ID,JD),4GQ(ID,JD),UG(ID,JD),UGN(ID,JD),
           7xPR(ID,JD),UP(ID,JD),UPZ(ID,JD),NZ(ID,JD),
           8E(ID,JD),E1(ID,JD),P(ID,JD),PD(ID,JD),
           9GZ(ID,JD),WP(ID,JD),KUP(ID,JD),KUG(ID,JD),
           A,WINDP(LD),
           COMMON/MC/V1JW,IV1JW(6),PW(6),
           REAL N,N1,N2,N3,N4,N5,N6,N7,N8,N9,N10,N11,N12
           DATA PG/0.0,0.0/ ,APROJ/0.0/ ,ZPROJ/0.0/ ,/0.0/ ,
           KK=KK+1
           IF (KK>KM) I=2,I2
           KK=KK+1
           IF (KK>KM) I=1,I2
           NTRY = 1
           GO TO 3
           2 NTRY = 2
           3 CONTINUE
           WRITE(6,1J9) KK,KK0,DT,PI,V
           1J9 FORMAT(1H,10X,3HKK=,1.6,10X,4HKK0=,1.6,10X,3HDT=.1PE14.6,
           2 5X,2HT=.1E14.6,5X,4PIN=E14.6)
           DO 6 I=1,NJW
           IJW=IJW(I)
           JNW=JNW(I)
           PL=PIW(I,JNW)+0.5*(IWW,JWW)*(WGN(IWW,JWW)*2+UGN(IWW,JWW)*2)
           2+0.5*4PN(IWW,JWW)*(WP(IWW,JWW)*2+UP(IWW,JWW)*2)
           6 PIN=PL*2.54/(980.616*453.59)
           WRITE(6,3J9) (1,IPX(I,I=1,NJW))
           100 FORMAT(1H,6(3X,2,HPW(I,J=1,2))=.1PE11.4)
           IF ((KK/5)-5-KK) 8,7,8

```

```

7 CONTINUE
  WRITE (8) KK, T, (PW(I), I=1, NJW), PB, VPROJ, ZPROJ, Y(4), Y(5),
 8 CONTINUE
  IF ((KK/KW)*KX-KX) 5,4,5
 4 CONTINUE
  WRITE (9) KK, T, DT, (Y(I), I=1, IRK)
  DO 9 I=1,1
  DO 9 J=1,1
 9 CP(I,J)=U(I,J)*W
  WRITE(10) KK, (KC(J), J=1, JM), (Z(I,J), I=1, IM),
 2 (CD(I,J), J=1, JM), (CP(I,J), J=1, JM), (CP(I,J), J=1, IM)
 2 WRITE(6,320) PN, CIN, WING, WINP, NIN
 320 FORHAT (14,2X,4) PIN=1PE11, 5,2X,4HCIN=E11,5,2X,5HWING,
 2 E11,5,2X,2HWING=E11,5,2X,4HNIN=E11,5
  CALL OUTPT (IH, P, IDJD, IM, JM, 10, 10HP, FIELD)
  CALL OUTPT (IH, 4G, 10, JD, IM, JM, 10, 10HWG, FIELD)
  CALL OUTPT (IH, JS, 10, JD, IM, JM, 10, 10HUG, FIELD)
  CALL OUTPT (IH, WP, 10, JD, IM, JM, 10, 10HWP, FIELD)

```

TWO DIMENSIONAL GAS PARTICLE FLOW

```
CALL OUTPT (1H0, UP ,1D, JD, IM, JM, 10, 10HUP FIELD )
CALL OUTPT (1H0, C ,1D, JD, IM, JM, 10, 10HC FIELD )
CALL OUTPT (1H0, N ,1D, JD, IM, JM, 10, 10HN FIELD )
CALL OUTPT (1H0, E1 ,1D, JD, IM, JM, 10, 10HE1 FIELD )
5 CONTINUE
RETURN
END
```

TWO DIMENSIONAL GAS PARTICLE FLOW

```
SUBROUTINE LCFLU (U,L)
IF (U) 2·1·1
1 L=0
2 RETURN
2 L=1
3 RETURN
END
```

```
CNTR0560
CNTR0590
CNTR0600
CNTR0610
CNTR0620
CNTR0630
CNTR0640
```

```
LOFU0010
LOFU0020
LOFU0030
LOFU0040
LOFU0050
LOFU0060
LOFU0070
```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE UNEQRCIM(RM,IR,RR,R,I,D)
DIMENSION R(1:D)
FIRSFLOAT(IR)
FINSFLOAT(IR)
R=1.0
DO 1 K=1,5
EX=EXP(-W*(FIR+FIR-2.0))+(1.0-EXP((-2.0*B*(FIR*I,0))))*RM/RR
A=ANALOG(EX)/(FIR-FIR)
WRITE(6,101) K-3,1M,1,RR,R
101 FORMAT(1Z3,3X,24K2,15.3X,2H8.1PE14.6,3X,3H1H2,15.3X,
23419=12,3X,3H4H,E14.6,3X,2H33.8'E14.6)
1 CORTINUE
DO 2 K=6,25
F1=SINH((B*(F13-1.0))
F2=RR*SINH((B*(F14-1.0))
D2=F1*F2*(FIR-1.0)*COSH(B*(FIR-1.0))-RR*(FIR-1.0)*COSH(B*(FIR-1.0))
D2=F1*(FIR-1;0)**2*F2*(FIR-1;0)**2
D3=SNGL(D2)/DBLE(D2)/DBLE(D1)*DBLE(D1)/DBLE(D1)
2 DBLE(D2)
R=R+78*(6,1J2)*JCB'B3,5,3X,3H99.8,1PE14.6,3X,2H8.1E14.6)
102 FORMAT(1H,3X,24K2,15.3X,2H99.8,1PE14.6,3X,2H8.1E14.6)
IF (ABS(D3)-1.0E-7)>3.02
2 CONTINUE
3 ASR/SINH((3*(FIR-1.0)))
4 DQ 4 I=1:I'
4 DQ 1=A*SINH(B*FLOAT(I-1))
RETURN
END

```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE NZLNP (T1,PIND,CIND,WINDP,NIND,T,PIN,CIN,WING,
2 WIND,WIN,LD)
2 REAL(WIND,WIN)
DIMENSION T(LD),PIND(LD),CIND(LD),WINDG(LD),WINDP(LD),NIND(LD),
DATA LLL/1/
GO TO (1,2),LLL
1 T1=T1(1)
2 T2=T1(2)
3 I=1
4 LLL=2
5 IF (T-T1) 7,3,3
6 IF (T-T2) 10,10,11
7 KS=I+1
8 DO 9 K=KS,D
9 SK
10 IF (T1(K)-T) 4,5,6
11 CONTINUE
12 J=J
13 T1=T1(1)
14 T2=T1(I+1)
15 GOTO 10
16 I=J-1
17 T1=T1(1)
18 T2=T1(I+1)
19 GO TO 10
20 ME=-I
21 DO 8 M=1,M
22 N=I*M
23 IF (T1(N)+T) 9,9,8
24 CONTINUE
25 T2=T1(N+1)
26 8N
27 T1=N+1
28 T2=T1(1+1)
29 IF 2*T2-PIND(I)+TF*PIN(I+1)
30 PIN=TF*2*PIN(I)+TF*PIN(I+1)
31 CIN=TF*2*CIND(I)+TF*CIND(I+1)
32 WING=TF*2*WINDG(I)+TF*WINDG(I+1)
33 NZL10010
34 NZL10020
35 NZL10030
36 NZL10040
37 NZL10050
38 NZL10060
39 NZL10070
40 NZL10080
41 NZL10090
42 NZL10100
43 NZL10110
44 NZL10120
45 NZL10130
46 NZL10140
47 NZL10150
48 NZL10160
49 NZL10170
50 NZL10180
51 NZL10190
52 NZL10200
53 NZL10210
54 NZL10220
55 NZL10230
56 NZL10240
57 NZL10250
58 NZL10260
59 NZL10270
60 NZL10280
61 NZL10290
62 NZL10300
63 NZL10310
64 NZL10320
65 NZL10330
66 NZL10340
67 NZL10350
68 NZL10360
69 NZL10370
70 NZL10380
71 NZL10390

```

UINP\*TF2\*WINCP(1)+TF\*WINDP(1+1)  
NIN\*TF2\*WINC(1)+TF\*NIND(1+1)  
RETJRI  
END

NZL10400  
NZL10450  
NZL10420  
NZL10430

TWO DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE RK2 (CPIV,CNTRL,Y,DY,A,R,T,DT,N,DTM)
SECOND ORDER RUNGE KUTTA
NTRY IS A DESIGNATED ONE OF THE VALUES LISTED BELOW IN CNTRL
CNTRL CONTINUES INTEGRATION
NTRY = 1 RETURN FROM RUNGE KUTTA
NTRY = 2 RETURN FROM RUNGE KUTTA
NTRY = 3 REPEAT STEP WITH NEW DT GIVEN IN CNTRL
NTRY = 4 CONTINUE INTEGRATION WITH FIXED STEP
PARAMETER NRKD=25
DIMENSION Y(NRKD),DY(NRKD),A(NRKD),R(NRKD),YST(NRKD)
EXTERNAL DERIV,CY,V
THR10=1.0E-03,THR2=0.5
C=0.5
BETA=C/5/SAH
ALPHA=1.0-BETA
CALL DERIV (Y,DY,T)
CALL CNTRL (Y,DY,C,T,NTRY)
TST=T
DO 5 I=2,N
YST(I)=Y(I)
5 CYST(I)=DY(I)
6 IF (DT) 8,7,8
7 WRITE (6,10)
101 FORMAT (1H,20X,17HSTEP SIZE = ZERC.)
RETURN
8 T=TST+5*DT
9 Q(1)=YST(1)+CY*DY(1)+BETA*D(Y(1))
CALL DERIV (Y,DY,T)
T=TST+DT
DO 10 I=2,N
10 Y(I)=YST(I)+DT*(ALPHA*D(Y(I))+BETA*D(Y(I)))
CALL DERIV (Y,DY,T)
SOCM=C/0
DO 13 I=1,N
E(Y(I))=(YST(I)+0.5*DT*D(Y(I))+DY(I)))
C=A(I)+R(I)*ABS(Y(I))
IF (C) 12,11,12
11 WRITE (6,13)
132 FORMAT (1H,20X,27HA(1)+R(1)*ABS(Y(1)))=0 AT I = + 16)

```

RETURN  
12 EOC=ABS(E/C)  
C EOC=NMAX1(EOC'EOCM)  
IF (EOC>EOCM) 13:13.901  
901 EOC>EOC  
LSV=1  
13 CONTINUE  
1F (EOC<1.0) 17,17,14  
14 T=TST  
DO 15 I=1,N  
Y(I)=YST(I)  
15 DY(I)=DYST(I)  
CALL IJM (L8V 'EOCM')  
DO 16 J=1,40  
EOCM=EOCM/10.0  
DT=QT/THR10  
IF (EOCM>0.31 6,5,16  
16 CONTINUE

TWO DIMENSIONAL GAS PARTICLE FLOW

```

GO TO 6
17 CALL CNTRL(Y,UY,DT,T,NTRY)
    GO TO (21,18,19,4),NTRY
18 RETURN
19 TSTST
    DO 20 I=1,4
        Y(I)=YST(I)
20 CYC(1)*CYST(I)
    GO TO 6
21 IF (EOCH=3,3) 25,25,22
22 DT=DT/THR13
    CALL IJ1 (-SY, EOCM)
    GO TO 4
23 IF (EOCM-C,03) 1, 26,4,4
25 DT=DT/THR13
    IF (ABS(DT)-ABS(DTW)) 4,4,24
24 DT=ABS(DT)*DT/ABS(DT)
    GO TO 4
END
RK2 0580
RK2 0590
RK2 0600
RK2 0610
RK2 0620
RK2 0630
RK2 0640
RK2 0650
RK2 0660
RK2 0670
RK2 0680
RK2 0690
RK2 0700
RK2 0710
RK2 0720
RK2 0730
RK2 0740
RK2 0750
RK2 0760

```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE LJM (LSV, EOCM)
PARAMETER IJ=25, JD=15, LD=400, NRKD=2625
COMMON /ALL/ F (1:20,JD,7), DF (10,JD,7), IS, IA, IB, IM, JA, JB, JM, LT,
VOLP, WM, APF, VFLNAX, PAV, FL, RC, KW, KK, KM, PI, N, IRK, RHOP,
T1 (LD), PI, YP (LD), CIND (LD), XIND (LD), NIND (LD),
T2 (LD), DELZ (ID), DELZZ (ID), RLYD, RR (JD), DELR (JD), DELR (JD),
DELZ (JD), VY (ID), VZ (ID), VY (JD), VZ (JD),
42 (JD), ARD (ID, JD), ARD (ID, JD), ARD (ID, JD),
SRV (ID, JD), S (ID, JD), C2 (ID, JD), CR1D, JD), CR1D, JD),
SGN (ID, JD), SGD (ID, JD), SGD (ID, JD), SGD (ID, JD),
7WPR (ID, JD), UP (ID, JD), UPZ (ID, JD), UP (ID, JD), UPZ (ID, JD),
BE (10, JD, FEI (10, JD), P (ID, JD), PR (ID, JD), DR (ID, JD),
9C2 (ID, JD), KUP (ID, JD), LWC (ID, JD), KUG (ID, JD), GZ (ID, JD),
A, WINDP (LD),
L=U
DO 2 I=2,14
1SV=1
DO 2 J=2,14
1SV=1
LSV=J
IF (J .EQ. 2 .AND. I .LT. IS) GO TO 2
DO 1 N=1,7
MSV=N
L=L+1
IF (L .EQ. 1) L=304
1CONTINUE
2CONTINUE
3CONTINUE (6,101) EOCM, LSV, LSV, JSV, MSV
WRITE (6,10X,5) EOCM, IPE12,5,10X,2HL=,16,10X,2HL=,16,10X,
101 FORMAT (4H,10X,5)HEOCM=,IPE12,5,10X,2HL=,16,10X,2HL=,16,10X,
2 24J=,16,14X,2HL=,16,10X,2HL=,16,10X,2HL=,16,10X,2HL=,16,10X,
RETURN
END

```

TWO DIMENSIONAL GAS PARTICLE FLOW

```

SUBROUTINE OUTPT (IPC,F,JD,IM,JM,NL,LABEL)
DIMENSION I(10,JJ),LABEL(22),LAB2(20)
DATA LBW/64/
GO TO 200
ENTRY OUTPT7 (IPC,G,K3,10,JD,IM,JM,NL,LABEL)
DIMENSION G(10,JJ,7)
DO 201 I=1,14
DO 201 J=1,14
201 F(I,J)=G(I,J,K3)
203 CONTINUE
JMM=MING(JM,K2)
NW=I+(NL-1)/6
NST=10-(NL-1)/2
DO 1 I=1,20
1 LAB2(I)=NL
1 DO 2 I=1,NP
2 NST+1-I
2 LAB2(K)=NL43EL(1)
2 WRITE(6,101) IPC,(LAB2(I),I=1,20),(J,JMM)
101 FORMAT(1A,20A,/,1H,2X,1H,2X,2HJ,12,11110)
102 WRITE(6,102) I,(F(I,J),J=1,JMM)
102 FORMAT(1H,13,1PE10.3,1E10.3)
102 RETURN
END

```